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RESOURCE GUIDE

Department of the Interior
HAZARDOUS MATERIALS MANAGEMENT CONFERENCE

HAZMAT 93

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DISCLAIMER

The purpose of this Resource Guide is to provide the user with an overview of the information presented at the Department of the Interior Hazardous Materials Management Conference, held May 10-13, 1993, in Denver, Colorado. Additional information related to hazardous materials management, DOI and DOI bureau contacts, and other information is provided as a resource for those interested. In no way should the Resource Guide be considered as providing legal advice. If legal advice is sought, an appropriate solicitor must be consulted.

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INTRODUCTION

INTRODUCTION

"The Department of the Interior is committed to a leadership role in preserving our Nation's heritage. This commitment is based upon the public trust, requiring the use of scientific, cost, effective, and innovative techniques to better manage and restore our lands and facilities." Secretary Bruce Babbitt

It is within the context of these words that the Office of Environmental Affairs (OEA) is hosting the first Department of the Interior Hazardous Materials Management Conference. This conference has been organized by a task group from OEA and the U.S. Geological Survey, supported by a steering committee representing other Interior bureaus and offices.

The purpose of the conference is to provide Interior bureaus and offices with training and information on the environmental laws and regulations concerning the cleanup of sites, liability, proper management of hazardous materials, and waste reduction strategies.

The conference will also provide opportunities for Interior bureaus to demonstrate their technical, consultative, and other resource capabilities which address the assessment, investigation, and cleanup of sites.

A purpose of any conference is to provide a forum where people can meet and exchange ideas and experience. At the DOI HazMat Conference, bureau hazardous materials managers and technical staff can meet to share information and ideas that will benefit all parties.

The purpose of this Resource Guide is to provide participants with an information resource on HAZMAT issues. Abstracts provided by the Plenary, Workshop, and Poster Session participants will be included. In addition, the Guide will include a listing of DOI Bureau and Office personnel involved with HAZMAT issues and their responsibilities and additional resource information on HAZMAT issues.

PLENARY SESSIONS

Technology Innovation Office

Office of Solid Waste and Emergency Response
United States Environmental Protection Agency
Washington, D.C.

Mission

The mission of the Technology Innovation Office (TIO) is to increase applications of innovative treatment technology by government and industry to contaminated waste sites, soils, and groundwater. Increased usage will be accomplished through the removal of regulatory and institutional impediments and the provision of richer technology and market information to targeted audiences of Federal Agencies, States, consulting engineering firms, responsible parties, technology developers, and the investment community. The scope of the mission extends to Superfund sites, corrective action sites under the Resource Conservation and Recovery Act (RCRA), and underground storage tank clean-ups. By contrast, TIO is not a focus for EPA interest in treatment technologies for industrial or municipal waste streams, for recycling, or for waste minimization. Other offices address these special interests.

For purposes of remediation, innovative technologies do not include rotary kiln incineration, conventional stabilization or other methods where sufficient performance and cost information are available. Land disposal technologies are also not included within the scope of TIO's interests. Innovation in thermal methods, bioremediation, physical/chemical techniques and groundwater extraction and treatment technologies is of principal interest. Innovative monitoring methods are of interest, but are a secondary priority.

Approach

TIO will influence the increased use of innovative technologies by working with and through knowledgeable individuals and groups both inside and outside EPA. TIO accomplishes its internal mission as a partner with other waste program offices and EPA's Office of Research and Development.

Within the Agency, TIO exercises policy leadership and sets expectations, assists in the implementation of demonstrations of technologies under the Superfund Innovative Technology Evaluation (SITE) program, analyzes trends in Agency technology decisions, helps screen technology types and vendors, and serves as a champion for Agency attention to innovative technologies. A collateral objective for TIO is brokering the transfer of information on the cost and performance of all alternative technologies for waste remediation.

Beyond EPA, TIO is engaging the principal stakeholders in innovative site remediation -- consulting engineers, responsible parties, technology vendors, venture capitalists, universities, States and professional associations -- in the challenge to increase the use of innovative technologies. This joint work involves both identifying mutual interests between and among these parties and EPA waste programs and then devising mechanisms to act upon them. Because EPA is a member of the family of Federal agencies interested in lower cost, innovative treatment technologies, TIO is establishing a Federal Remediation Technologies Roundtable to maximize the sharing of available Federal experience.

Mechanisms for Action

The primary objectives of TIO are to identify and enhance incentives to increase innovative technology application and to advocate innovation through removal impediments. TIO will explore opportunities within the existing statutory and regulatory frameworks for additional flexibility in policies, permitting, State grants, and contracting procedures to stimulate greater use of innovation. Recognizing the authority of the States in executing the hazardous waste programs, TIO will explore with the States opportunities for them to exercise further leadership in technology innovation.

Another area of interest is the availability of cost and performance information on new technologies. Data are frequently missing to support developer claims; in certain instances, a developer may possess test data, but lack any data sets containing application information that convinces a technology user of their validity. TIO will address this critical problem by developing minimum data sets that a developer can satisfy. Criteria will be developed through a consensus of EPA, States, consulting engineers and developers for the basic sets of data that will provide an extra level of confidence to vendor claims. The objective of the data is to advance the likelihood that a technology will be fairly considered during engineering feasibility studies. Hopefully, technology vendors will realize a substantial market advantage by providing such basic data. TIO anticipates that this program will be viewed as an incentive by the vendor community.

Market information is also needed to clarify the opportunities for technology vendors. They are unclear where to market their innovative systems because insufficient information about the characteristics of waste sites is available. TIO will begin by providing both profiles on the overall population of Superfund sites, and information on sites that are currently in the decision process. An indirect benefit of this effort will be to stimulate new technology development.

TIO will ensure that inventors and vendors are aware of "incubator" facilities that provide a full-range of services from testing and evaluation to assistance in commercializing technologies. The existing "incubators" are both non-profit and for-profit and differ in the amount of financial assistance provided to the developer.

Dissemination of information on technologies is a critical component of TIO's mission. There are a number of specific mechanisms to communicate policy and information on innovative technologies and other technical assistance. First, OSWER operates training programs nationwide that are especially responsive to the changing needs of EPA regional staff by designing new course development and encouraging innovative training technologies. TIO also operates a highly regarded human resource development initiative -- the On-Scene Coordinator/Remedial Project Manager Support Program -- for front-line Superfund employees. TIO will seek to extend its successes in this area to other professionals in the hazardous waste management field.

TIO will optimize the use of the electronic bulletin boards, newsletters, monographs, technical briefs, brochures, trade journal articles, and conference presentations. It recognizes the importance of up-to-date and comprehensive mailing lists within EPA and for clients in other Agencies, the States, and for private stakeholders.

TIO is not a grant-making organization -- other organizations have that mandate for innovative technology development, technology transfer, and training. TIO will seek to enable outside groups to form partnerships and networks and seek to develop client relationships to increase the level of innovative technology use.

# # #

United States
Environmental Protection
Agency

Office of Solid Waste
and
Emergency Response

Technology
Innovation Office
January, 1993

EPA

Two Years Later: What Has Been Done to Reduce Impediments to the Use of Innovative Technology

BACKGROUND

A driving force for the development of innovative remediation technologies is the commitment by the Superfund program to seek the development of more cost-effective solutions for the permanent treatment of contaminated sites. In each of the past four years, seventy percent of all source control Records of Decision for Superfund (through fiscal year 1991) include some kind of treatment technology. In fiscal year 1991, for the first time, over half of the treatment technologies selected were innovative. These facts demonstrate an ongoing commitment to deploy state-of-the-art technology solutions. The Superfund Program created the Technology Innovation Office in response to the 1989 Superfund 90-day management study. TIO's mission is to increase applications of innovative treatment technologies by government and industry to contaminated waste sites, soils, and ground water.

In October, 1990, the Technology Innovation Office, in conjunction with the National Advisory Council on Environmental Policy and Technology (NACEPT), held a workshop to develop an action agenda for the use of innovative remedial technologies by consulting engineers. The purpose of the workshop was to reduce the barriers that impede the use of innovative technologies to remediate contaminated soils and ground water at Superfund sites, corrective action sites under the Resource Conservation and Recovery Act (RCRA), and underground storage tank sites. Workshop participants included representatives from engineering firms, professional societies, universities, state environmental agencies, industry, other federal agencies, and EPA. A similar workshop was held in June, 1992, to develop a second-phase agenda to specifically increase research, development, and application of innovative *in situ* treatment technologies for contaminated ground water.

Some of the barriers that were addressed during these two workshops related to information sharing, regulatory uncertainty and liability, training and professional development, research and development gaps, pump-and-treat technology limitations, and lack of incentives. Participants discussed these problems, as well as others, and suggested specific actions that could be initiated in the public and private sectors to overcome these barriers. EPA and others have responded to these needs. The following items list the accomplishments that have been made in response to the workshops.

PROCESS IMPROVEMENTS

- Issued an OSWER directive on furthering the use of innovative treatment technologies in Superfund and other EPA waste-related programs (OSWER Directive 9380.0-17FS, August, 1991):
  - Encourages reasonable risk-taking in selecting innovative treatment technologies.
  - Requires innovative technologies to be routinely considered as an option in engineering studies.
  - Establishes initiatives and new procedures that will provide incentives for broader use of innovative technology.
- Monographs are being developed to outline operating parameters for eight innovative and established technologies through a Cooperative Research Agreement with the American Academy of Environmental Engineers and its associated professional organizations. This project, called Wastech '92, is sponsored by EPA, the Department of Energy (DOE), and the Department of Defense (DOD). Expert workgroups have produced draft manuals that will undergo peer review. Completed manuals are anticipated to be available by early 1994.
- Revised the *Innovative Hazardous Waste Treatment Technologies: A Developers Guide to Support Services—Second Edition* (EPA 540/2-91/012) to aid new technology commercialization.
- Developed Quick Reference Fact Sheets on the regional experience with procurement of innova-

tive technologies at remedial Superfund sites (EPA/542/F-92/012) and removal Superfund sites (EPA/542/F-92/013).

- Developed *Strategy to Increase the Use of Innovative In Situ Treatment Technologies for Contaminated Ground Water* (EPA/542/F-92/025, December, 1992).
- Active outside review by consulting engineers and scientists of *Treatability Study Guidelines* (EPA/540/2-89/058) being produced by EPA's Office of Research and Development.

REGULATORY

- The Superfund Response Action Contractor Indemnification Rule (58FR5972) issued on January 25, 1993, included provisions that allow lower deductibles for contractors using innovative treatment technologies.
- The Corrective Action Management Unit (CAMU) and Temporary Unit Rule (58FR8658) was promulgated on February 16, 1993, as an optional provision under Subpart S of 40 CFR 264. This rule is expected to result in more on-site waste treatment; less reliance on incineration; greater reliance on innovative treatment technologies; and lower incidence of capping waste in place without treatment.
- Delegated authority to issue Site Specific Treatability Variances for contaminated soils and debris to the Regions (OSWER Delegation 8-40).
- Authorized more states for the Treatability Exclusion Rule; Research, Development, & Demonstration Permit Authority; and Subpart X Permit Authority. These authorizations will simplify approvals and allow more flexibility for testing and demonstrating innovative treatment technologies (9380.3-09FS).
- Promulgated a rule on August 18, 1992, for Land Disposal Restriction of Contaminated Debris, which allows more flexible treatment standards than under the original Land Disposal Regulations (40CFR268).

RESEARCH, DEVELOPMENT, AND DEMONSTRATION

- The EPA-led Bioremediation Action Committee (BAC) has improved bioremediation as an innovative technology for site remediation. Since 1991, the BAC, an affiliation of industry, academia, and government officials, has:
  - Identified high-priority research needs through an April, 1991, workshop of government, university, and industry representatives.
  - Produced interim guidance for preparing bioremediation spill response plans to help On-Scene Coordinators determine whether bioremediation agents or methods are safe and effective for oil spills.
  - Set protocols that can be used to collect data to identify safe and effective products for bioremediating oil spills in the *Oil Bioremediation Products Testing Protocol Methods Manual.* This is available from the National Environmental Technology Application Corporation (1-800-48NETAC).
- The Bioremediation Field Initiative was established by EPA's BAC to provide EPA and State project managers, consulting engineers, and industry with timely information regarding new developments in the application of bioremediation at hazardous waste sites. The initiative provides evaluation of the performance of selected full-scale field applications. Nine sites have been selected and are currently being evaluated. Sites being evaluated include:
  - Land treatment of creosote and PCP using indigenous microorganisms and white rot fungus.
  - Bioventing of jet fuel and coal tar.
  - *In situ* treatment of groundwater contaminated with solvents, waste oils, refined petroleum, or creosote.
  - Natural biodegradation of landfill leachate in ground water.
- Clean Sites, Inc., organized a users group of Fortune 500 companies to collaborate with the Air Force, Army, and EPA to evaluate innovative technologies at Federal Facilities that are applicable to corporate clean-up problems. The Cooperative Research and Development Agreement was signed in December, 1992. McClellan Air Force Base in Sacramento, CA, will be the first demonstration site.
- Proposal developed to create a National Bioremediation Field Research Center for applied public and private research and development on the use of bioremediation. Additional support and funding will be provided by a consortia of states and federal agencies, EPA Hazardous Substance Research Centers, and corporations. Wurtsmith Air Force Base in Michigan is a candidate site.
- Established a Ground-Water Remediation Technology Research and Analysis Center. The Robert S. Kerr Laboratory in Ada, OK, will operate the center on behalf of public and private sector users. The center will:
  - Track ongoing ground-water research and development on a continuing basis.
  - Promote coordination between public and private research groups.
  - Encourage the demonstration of promising remediation research.

  - Form a panel of experts to analyze trends and directions in ground-water research.

- Inventoried the status of *in situ* ground-water remediation technologies in *In Situ Treatment of Contaminated Ground Water: An Inventory of Research and Demonstration.* For a copy of this report, please contact Rich Steimle of TIO at 703-308-8846.

- Continued tracking the status of all innovative treatment projects in Superfund in *Innovative Treatment Technologies: Semi-Annual Status Report*, October, 1992 (EPA/542/R-92/011). This report (to become annual beginning in Spring, 1993) lists each Superfund site using an innovative technology, the waste treated, implementation status, and project manager, and gives summary data for completed projects. The latest report also begins tracking some innovative projects at DOD and DOE sites.

INFORMATION SHARING

- Developed a series of satellite video conferences sponsored by the Air and Waste Management Association and the Hazardous Waste Action Coalition in cooperation with the U. S. Air Force, DOE, the Water Environment Federation, EPA, the American Institute of Chemical Engineers, the National Solid Waste Management Association, the Association of State and Territorial Solid Waste Management Officials, and the Technology Innovation and Economics Committee of the EPA's National Advisory Council on Environmental Policy and Technology. Past seminars were: *Bioremediation: The State of Practice in Hazardous Waste Remediation Operations* (January 9, 1992), and *Bioventing and Vacuum Extraction: Uses and Applications in Remedial Operations* (April 15, 1992). The newest seminars include *Thermal Treatment—Thermally Enhanced Volatilization* (February 18, 1993), and *Changing Molecular and Physical States* (March 18, 1993).

- Produced the Vendor Information System for Innovative Treatment Technologies (VISITT) (EPA/542/CR-92/001), which provides current information on innovative technology vendors, their products, and capabilities. The database contains 155 innovative technologies offered by 97 vendors. There are almost 7,000 users registered to date. Orders may be faxed to (513) 891-6685.

- Established the Federal Remediation Technologies Roundtable to serve as an information exchange network for and about federal agencies conducting applied research and development on innovative hazardous waste remediation techniques. Subcommittees on evaluation of monitoring and measurement technologies and ground-water remediation technologies have been formed.

- Revised publication of information on federal agency activities, information, and demonstration of innovative treatment technologies: *Accessing Federal Data Bases for Contaminated Site Clean-up Technologies* (EPA/542/B-92/002); *Bibliography of Federal Reports and Publications Describing Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation* (EPA/542/B-92/001); and *Synopses of Federal Demonstrations of Innovative Site Remediation Technologies* (EPA/542/B-92/003).

- Enhanced EPA's Clean-Up Information (CLU-IN) electronic bulletin board to serve project managers and other users interested in innovative treatment technologies. This board offers a number of information sources that may be read on-line in a bulletin format or as files that can be downloaded. Contents include *Federal Register* notices on hazardous wastes, listings of EPA publications, a calendar of EPA training programs, directories of EPA experts on hazardous waste clean-up, and listings of National Priority List sites. (System operator—301-589-8368.)

- Published three regular newsletters devoted to current application of innovative technology: *Tech Trends* (EPA 542/N-92/001); *Bioremediation in the Field* (EPA 542/N-92/004); and *Ground Water Currents* (EPA/542/N-92/006).

- Published *Innovative Treatment Technologies: Overview and Guide to Information Sources* (EPA/540/9-91/002). Gathers in one volume a wide variety of existing EPA technical guidance and information.

- Produced ten citizen Fact Sheets on innovative technologies:

  - *A Citizen's Guide To Innovative Treatment Technologies For Contaminated Soils, Sludges, Sediments, and Debris* (EPA/542/F-92/001)
  - *A Citizen's Guide To How Innovative Treatment Technologies Are Being Successfully Applied At Superfund Sites* (EPA/542/F-92/002)
  - *A Citizen's Guide To Soil Washing* (EPA/542/F-92/003)
  - *A Citizen's Guide To Solvent Extraction* (EPA/542/F-92/004)
  - *A Citizen's Guide To Glycolate Dehalogenation* (EPA/54/F-92/005)
  - *A Citizen's Guide To Thermal Desorption* (EPA/542/F-92/006)
  - *A Citizen's Guide To In Situ Soil Flushing* (EPA/542/F-92/007)
  - *A Citizen's Guide To Bioventing* (EPA/542/F-92/008)
  - *A Citizen's Guide To Using Indigenous and Exogenous Microorganisms In Bioremediation* (EPA/542/F-92/009)
  - *A Citizen's Guide To Air Sparging* (EPA/542/F-92/010)

Spanish versions of these fact sheets will be available in early 1993.

Two Years Later: What Has Been Done to Reduce Impediments to the Use of Innovative Technology

- **Developed a teaching outline and support materials for a one-semester course on innovative technologies for use by graduate Environmental Engineering Departments. The course, developed by the University of Connecticut in association with the Association of Environmental Engineering Professors, will be available in Summer, 1993.**
- **Delaware and New Jersey hosted two training sessions for states interested in taking the lead in innovative technology development and uses.**
- **Workshop on *Utilizing Bioremediation Technologies: Difficulties and Approaches*, which developed guidelines for bringing bioremediation projects to the field and was supported by EPA and other public and private entities (Rutgers University, Cook College).**
- **Published numerous EPA documents related to innovative technologies, all of which are summarized biannually in *Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation—A Bibliography of EPA Information Resources* (EPA/542/R-92/004).**

TRAINING FOR EPA'S REGIONAL SUPERFUND PROGRAMS

An important means of increasing the selection of innovative technologies for contaminated sites is to provide consistent nationwide training to EPA's Regional Superfund staff. Basic and specialized training prepares the RPM and OSC to make decisions in selecting and implementing remedial technologies. Training provides the OSC and RPM with knowledge of the regulatory and legal processes involved in cleanup under the EPA waste programs. Also, through continuing education, training provides skills in the diverse science and engineering fields needed for site investigation and remediation. Training programs include:

- CERCLA Education Center (CEC), which provides RPMs a basic understanding of the laws, regulations, policies, and processes of the Superfund program. Course curriculum includes:
  - Fundamentals of Superfund
  - The Enforcement Process
  - The Removal Process
  - The Remedial Process
  - Community Relations
  - Advanced Superfund Contracts Management

  Additional course curriculum to be developed in 1993:
  - Federal Facility Enforcement
  - Treatment Technologies
- Orientation and training manuals include:
  - The CERCLA/Superfund Orientation Manual
  - The OSWER Source Book
- The Superfund University Training Institutes (SUTIs), which provide advanced, specialized training to Superfund staff. SUTIs' offerings include:
  - University of Virginia—training for emergency chemical spills and releases
  - University of Nevada, Las Vegas—site assessment
  - University of Cincinnati—treatment technologies
  - Rice University—ground-water contamination
- Alternative training methods to reduce training costs include:
  - Interactive Video for Land Disposal Restrictions Enforcement
  - Satellite broadcast of CEC's Enforcement Process training

EPA documents are available by faxing a request to
(513) 891-6685 or writing to:

National U.S. EPA Center for Environmental Publications and Information
11029 Kenwood Rd., Building 5
Cincinnati, OH 45242

There may be a charge for some of these documents.

WORKSHOP TOPICS

RCRA Hazardous Waste Inventory Plan

by

Gary W. Kramer
Bureau Safety Manager
U.S. Geological Survey

Before developing and implementing a hazardous waste management program at any facility, waste types must be identified and quantities of hazardous waste being generated at each facility must be determined. This workshop will discuss the value of a hazardous waste inventory plan.

An inventory plan should be established to identify the waste, generator, and location; classify the waste; estimate quantities; know what safety or health concerns are present for each waste; describe container type and condition; and know the start date of accumulation. Also, by establishing a process for determining possible reuse by in-house personnel, the inventory plan can be an excellent mechanism for reducing the quantity of waste generated at a facility. Often overlooked, procedures for reconciling the inventory after each hazardous waste pickup must be established.

A hazardous waste inventory plan facilitates the waste removal process. By knowing the quantities and types of waste, one can determine whether a contract is needed or whether the waste can be removed under a small purchase agreement. If a contract is necessary, the inventory facilitates defining the scope of work and specific services required.

The workshop will discuss an inventory plan currently used by the U.S. Geological Survey at its National Center in Reston, Virginia to manage waste generated in over 100 chemical laboratories and other locations.

8761

ABSTRACT Traditional and Non-traditional Solutions

Merlin Landfill, Josephine Co. Oregon

Conn, James E., BLM, Medford District, 3040 Biddle Road, Medford, OR 97504
Figure 5 from City of Grants Pass Annual Report to Oregon Dept. of Environmental Quality (DEQ)

In May, 1991 BLM sent the City a letter to show cause why the lease should not be suspended. This action was prompted by a general sense that the City was not taking aggressive action at the landfill and that the State regulator, DEQ, was not forcing the issues. The City had an alternative site for disposal but that site was 35 miles away and an unlined landfill like Merlin. The "show cause" letter gave the City 30 days to respond. In July 1991 the City presented to BLM an alternative course of action which was no change, just keep on going. This plan was rejected by BLM. The City responded to the "show cause" letter by formally requesting a hearing before an administrative law judge but asked that the request be held until the City and BLM could conduct "meaningful" negotiations on the lease. A series of meetings were held in September through December 1991. The results being a substitute lease (same expiration date 6/14/2000) with new stipulations. Essential stipulations include:

- City to install an alternate water supply to down gradient users by 11/30/92. This has been completed.

- City to install a temporary plastic cover over the inactive portions of the footprint, moving the cover as activity moves by 8/30/92, completed.

- City to improve the existing leachate collection system and decommission the "fire pond" used to collect leachate by 11/20/92, completed.

- City to complete DEQ required Phase II Hydrogeologic Investigation by 8/30/92, complete.

- City to submit to DEQ a Draft Closure Plan for the landfill by 6/30/92, complete.

- City to design an Interim Ground Water Recovery System (e.g., Pump & Treat) by 6/30/94 with full implementation by 12/31/94. In process at this time.

How did the City Finance?

Tipping fees have increased twice and are expected to go up in July 1993. Volume at the site has not dropped with fee increases so far.

The estimate to close and monitor the site is approximately $20,000,000.00 all of which the City has agreed to pay.

S761

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ABSTRACT

Traditional/Non-Traditional Solutions

Bruce B. Talbot, Bureau of Land Mgnt.
3707 N. 7th Street, Phoenix, AZ 85014

When considering actions on contaminated sites on public lands, look at all the options available within the requirements of the National Contingency Plan. Priority concerns are: 1) protection of public health and safety and the environment, 2) agency and personnel liability, and 3) cost.

Recent changes in procedures and policy encourage both more effective and efficient ways in dealing with reducing risks and accelerating processes, HRSII and EPA's new Paradigm, (AKA, SACM). Three case studies in Arizona will illustrate some of these options; Peoria Auto Fluff, Bishop Creek Wire Burning and Escapule Waste Pesticide Dump.

Peoria Auto Fluff involved the dumping of 6,000 tons of residue from the remains of auto sheading after metal extraction. This waste was both buried and piled on the surface in the flood plane of a major river. A large scale removal action was the initial action of choice. This would reduce the risk of spreading the contaminate down stream and reduce the hazard ranking. The contaminates includes lead and PCBs.

Bishop Creek Wire Burning included four sites in dry washes which were discovered shortly before the rainy season. Stabilization and site consolidation with the assistance of EPA was the short term action selected. Eventual cleanup actions also offer a variety of options.

Escapule Wash was a pesticide dumping incident with an identified PRP. The LECC became involved and directed a cleanup by the ADEQ's contractor. The PRP plead quilty and was required to pay all cost in this cleanup, about $32,000.

PRP cleanups may be an under used resource. State laws may help. For example, Arizona law on mining hazards have felony provisions while Federal law does not. PRPs can also avoid many of procedural requirements of the NCP.

Remedial Investigation of Landfill Sites

CASE, H.L., U.S. Geological Survey, 1745 West 1700 South, Salt Lake City, Utah, 84104

During July 1988-92, the U.S. Geological Survey did a Remedial Investigation (RI) of contamination at Operable Unit 4 (OU 4), at Hill Air Force Base (AFB), Utah. Laboratory analyses of water samples detected 13 volatile organic and 2 inorganic contaminants in the shallow ground water in the area of OU 4. Trichloroethylene (TCE) was detected most frequently and in the highest concentrations, with a maximum concentration of 18,000 µg/L. The total volume of TCE in the saturated and unsaturated zones was computed to be equivalent to 353 gallons of pure TCE product, or about 6 drums. Landfill 1, one of two landfills at OU4, was determined to be the most probable source of TCE.

The objectives of the RI were to: 1. Characterize the nature and extent of contamination; 2. Determine the source(s) and fate of contaminants; 3. Develop a baseline risk assessment for the potential exposure pathways through soil, ground water, and air. (James M. Montgomery, Consulting Engineers, Inc. conducted the risk assessment studies working under a contract with Hill AFB.)

OU 4 overlies the Sunset and Delta aquifers, which are productive sources of drinking water and are used by Hill AFB and surrounding communities. Water in the Sunset and Delta aquifers generally is confined and occurs at depths of 300 and 600 ft below the landfills, respectively. Shallow ground water, in which contamination has been detected, overlies the Sunset and Delta aquifers.

Most of the sediments in the shallow ground-water system consist of clays and fine silt. Most ground-water movement near the landfills is in interfingered layers of sand and silt in the upper 30 to 60 ft of sediments. Orientation of the clay, silt, and sand layers in the shallow ground-water system is usually horizontal. Although downward vertical hydraulic gradients predominate in the shallow ground-water system, the horizontal component of average linear velocity is about 3,000 to 7,000 times greater than the vertical component. As a result, there has been no vertical percolation of contaminants to deeper aquifers.

Risk data available as of November 1991 (as determined by James M. Montgomery, Consulting Eng.) indicated that there were not any complete exposure pathways that presented any significant health risk to people living or working in the vicinity of OU4; however, more data need to be collected to adequately determine the risk associated with inhaling indoor air. The data also indicated that there was little potential for ecological harm as a result of the contaminants present at OU4. Human health risk associated with the occurrence of TCE, however, could develop in the future.

Remedial Investigation of Landfill Sites

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Characterization of Mine Tailings Sites

CORNELL, W. L., Supervisory Chemical Engineer, U.S. Bureau of Mines, Rolla Research Center, 1300 N. Bishop Ave., Rolla, MO 65401, Mardock, C. L., Geologist, U.S. Bureau of Mines, Albany Research Center, 1450 Queen Ave., S. W., Albany, OR 97321-2198

Federal land management agencies have made a commitment to clean up hazardous wastes on their lands. To accomplish this task cost effectively, a number of phases must be completed. The lands need to be surveyed to identify sites that may require remediation. Once a potential site has been identified, site characterization needs to be conducted.

Site characterization involves the use of tools such as geophysics, chemical and mineralogical analyses, historical analyses, and hydrology to characterize both the gross and material characteristics of the site. Site characterization, as the term relates to U.S. Bureau of Mines research, means the development of tools and techniques to accurately represent the contaminated materials on a site and their spacial effects on the local environment to allow the best decisions on cleanup at minimum cost.

Once proper site characterization has been completed, appropriate remediation decisions can be made and Bureau research has developed and is continuing to develop cost-effective treatment techniques based on the scientific characterization of both the site and its contained materials.

Assessment and Compliance of Solid Waste Disposal Alternatives for the Bureau of Indian Affairs

GERNERD, Kurt A., Office of Construction Management/DOI, 1849 C Street NW,
Washington DC 20240

A solid waste management program analysis was developed by the Office of Construction Management to determine solid waste alternatives for BIA agencies that will both reduce BIA liability and bring BIA agencies in compliance with regulations in an efficient and cost-effective manner. This paper describes a proactive, systematic approach to conducting an environmental compliance assessment at BIA locations nationwide, and preparing closure plans for BIA-owned solid waste disposal facilities that require closure. Analysis of solid waste management options is necessary for all Bureaus and Offices to ensure environmental compliance with Federal regulations and reduce environmental liability associated with the use of noncompliant facilities.

Community Relations

GOVERNMENT AUTHORITY VERSUS COMMUNITY INTERESTS, EPA's Smuggler Mountain Experience.

Pinkowski, Brian, U.S Environmental Protection Agency, 999 18th Street, Suite 500,
Denver, Colorado 80202

Communities across the nation are becoming involved in risk management decisions that were once the exclusive domain of governmental organizations such as the Environmental Protection Agency. This is particularly true of communities with roots in the mining industry. This involvement in local risk management threatens a nonuniformity in national risk management. This is because each community may have a different threshold for determining what is an "acceptable risk" and how much authority they allow the Federal agency to have in executing its Congressionally mandated mission.

Ethical difficulty arises when a community determines that medical information which shows an observable impact on their children should be the threshold for required environmental cleanup. Aspen, Colorado has made such a decision about the soil lead contamination left behind from the town's silvermining days.

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TSCA AND RCRA WASTE DISPOSAL

The "Real" Hazards of TSCA Waste Disposal

Lind, Scott L., U.S. Bureau of Reclamation, 1150 N. Curtis Rd., Boise ID 83706-1234, (208) 378-5036

Doe, Philip T., U.S. Bureau of Reclamation, Denver Federal Center, Denver CO 80225-0007, (303) 236-1061 ext. 255

The Bureau of Reclamation implemented a policy for the removal of all PCB's from its facilities and has often used hazardous waste contractors such as North American Environmental, Inc. (NAEI) for the removal and disposal of Toxic Substances Control Act (TSCA) and Resource Conservation and Recovery Act (RCRA) wastes. Contracts involving the disposal of RCRA and TSCA wastes historically have had little modification to provide for the required waste tracking. In most cases, contractors were paid-in-full following waste removal even though Certificates of Disposal or returned manifests had not been received. Wastes removed from Reclamation facilities were often "out-of-sight, out-of-mind".

As a hazardous waste contractor, NAEI had several transfer stations and storage sites located throughout the west. The NAEI facility located at the Freeport Center warehouse complex in Clearfield, Utah had received and stored wastes from 1986 until its seizure by EPA in 1992.

In August, 1990 NAEI submitted a Part B application to the EPA for the commercial storage of hazardous waste at the Clearfield facility. EPA denied the permit application in October 1990. NAEI continued operations until February 28, 1992, when EPA ordered the Freeport Center as property owner, to seize the warehouse. An agreement was reached between the Freeport Center and EPA to allow generators to remove their wastes to a permitted Treatment, Storage, and Disposal (TSD) facility until September 1, 1992, when the EPA Region VIII CERCLA Branch took over the site.

Reclamation scheduled to have all of its wastes removed before the September 1, 1992 deadline. Three days prior to the scheduled waste shipment, Reclamation was informed that the disposal costs would be 6.5 times the original estimate due to a presumed increased liability on the part of the TSD. Reclamation requested a variance from EPA in Washington DC and was told that a variance would be forthcoming. After the assurance from the consultant and the TSD that the surcharge would be waived if the variance was issued, Reclamation shipped the wastes. Within two weeks EPA had issued a written variance; however, the TSD had disposed all of the Reclamation wastes and demanded payment-in-full. The original $17,000 disposal cost had now inflated to over $100,000 and the total contract cost had gone from $61,000 to $175,000. Also, Reclamation has accumulated substantial administrative costs and has been named as a potential responsible party for the NAEI site.

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ABSTRACT

HAZARDOUS WASTE CLEANUP AND DISPOSAL ISSUES AND ACTIONS - CASE STUDIES

Team Approach to Discovery, Investigation, Prosecution and PRP Cleanup of Hazardous Waste Sites

MARTIN, Michael J., and GRIFFITH, Martin G., Bureau of Land Management, 2515 Warren Avenue, Cheyenne, Wyoming 82001, telephone (307) 775-6265/6093

***United States v. Pacific Enterprises Oil Company*, No. 129-176 (D. Wy. Jan. 22, 1992)**

In the first major criminal prosecution for hazardous waste dumping under the Federal Land Policy and Management Act (FLPMA), a company pled guilty to the illegal disposal of hazardous and solid wastes at three Wyoming oil fields operated on public land. Additional charges under the Resource Conservation and Recovery Act were dropped during plea negotiations. Pacific Enterprises Oil Company (PEOC) agreed to pay a total of $1,600,000 in fines. In a parallel State enforcement action PEOC further paid a penalty of $200,000 to the State of Wyoming.

The illegal disposal violations included allegations that PEOC buried hazardous waste, asbestos, scrap metal, pipes, and chemical drums and pumped chemicals from drums and spread them along dirt roads at the oil field. The violations occurred at the Notches Dome Oil Field and the Boone Dome Oil Field, both near Powder River, Wyoming, and at the Salt Creek Oil Field, near Midwest, Wyoming.

Under a plea agreement, in addition to the fine, PEOC paid restitution for the damage it caused to public lands by deeding 1,000 acres of land along the Green River in Desolation Canyon, Utah, to the federal government. The court also ordered the company to conduct remedial action required by federal and state authorities at the sites and to perform environmental compliance audits of its operations in Wyoming. PEOC could face additional criminal charges if violations disclosed by the audits are not addressed.

Team Approach

As illustrated by the following U.S. Department of Justice release, this investigation was the result of "TEAM WORK" on the part of Federal and State agencies...

...Barry M. Hartman, Acting Assistant Attorney General for the Environment and Natural Resources Division, said, "This case is the first major criminal prosecution under the Federal Land Policy and Management Act (FLPMA) and sends a strong message that pollution of public lands is unacceptable and will be prosecuted to the full extent possible under Federal law."

Hartman said, "We applaud the joint efforts of the Interior Department and the Environmental Protection Agency in this matter and, in particular, note our appreciation for the commitment to protection of the public lands demonstrated by the BLM."

Richard A. Stacy, U.S. Attorney in Cheyenne, said, "We compliment the BLM Law Enforcement staff in Wyoming, the Environmental Protection Agency in Denver, and the Wyoming Department of Environmental Quality for ensuring that public lands will not be used as dumping grounds for hazardous substances."...

As a result of this and other investigations in Wyoming associated with Federal environmental protection statutes, to include FLPMA, an Environmental Protection Coordinating Committee has been established in Wyoming. This committee is a subcommittee of the U.S. Department of Justice, Law Enforcement Coordinating Committee (LECC), and functions under the leadership of the United States Attorney for the District of Wyoming. This committee is comprised of Federal, State and local government agencies. To effectuate the purpose of this committee and to best meet the needs of the public, the following goals were established:

1. Communication among the federal, state and local agencies who are responsible for the integrity of the environment and the public health.

2. Coordination among those agencies to insure the proper characterization, and as appropriate, dissemination of information within the law enforcement community and to the public at large; and

3. Education of all levels of government and the community in order to assist them in recognizing violations of the environmental laws and regulations and to sensitize them to the threat to public health and the environment resulting from violations of those laws.

Disposal of Hazardous & Nonhazardous Waste From the Krejci Dump Site

MCCAIG, Robert E., Bureau of Reclamation, PO Box 25007, Denver, CO 80225

Since 1987 efforts have been underway to characterize and remove nonhazardous and hazardous wastes from the Krejci Dump Site, a part of the Cuyahoga Valley National Recreation Area in north-eastern Ohio. The Bureau of Reclamation has coordinated these efforts for the National Park Service since 1989, and although the task is still far from complete, these characterization and disposal activities have presented many challenges to the government, regulatory and contractual parties involved.

The Krejci Dump was operated as a municipal waste/salvage yard for approximately 40 years by the Krejci family. The National Park Service acquired the property by condemnation in the early 1980's. The National Park Service did not realize that hazardous wastes existed on the site until after they took full control of the property.

In an emergency response action, the U.S. Environmental Protection Agency worked to "stabilize" the site from 1988 into 1989. Approximately 2,730 drums and 4,500 cubic yards of hazardous and nonhazardous wastes were removed by the response action. Although the U.S. Environmental Protection Agency considered the site stabilized, funding limitations did not allow the continued use of U.S. Environmental Protection Agency contractors to complete waste removal.

The response action left approximately 2,000 drums, and 3,500 cubic yards of hazardous waste "staged" for removal. Also remaining were an estimated 33,000 tons of unconsolidated trash and debris, suspected to be nonhazardous. By interagency agreement, the National Park Service requested the Bureau of Reclamation to coordinate the remaining removal work, and to perform any studies necessary to "close the site."

Formal closure of the site required the involvement of the State of Ohio, and in April of 1991, the Ohio Environmental Protection Agency assumed regulatory authority for the site by issuing an administrative consent order to the National Park Service. The order requires the National Park Service to perform a remedial investigation/feasibility study of the site. As an interim action to the remedial investigation/feasibility study, the remaining removal of staged wastes and unconsolidated wastes was initiated.

The "staged" hazardous waste characterization, removal, and disposal has been performed through Bureau of Reclamation's requirements contract with a major environmental engineering company. Contracting for characterization began in 1990, and the removal and disposal was just recently completed. Numerous issues were encountered throughout the process.

These issues have included:

-Developing and negotiating fixed price delivery orders to characterize wastes, procure removal and disposal services, and implement removal and disposal activities.

-Coordinating technical reviews of all work plans by Ohio Environmental Protection Agency.

-Providing contractor indemnification versus obtaining third party pollution liability coverage for the contractor.

-Sampling for dioxin contamination, detecting it, and then dealing with the uneasiness and confusion the detection of this contaminant induces within the disposal industry.

-Coordinating the government's need to review the adequacy of proposed disposal facilities while not impacting the procurement process of the contractor in a manner which would invite bid protests.

-Laboratory data which was found to be in error at a time when removal activity was underway.

-Obtaining substantive progress on the removal and disposal tasks when serious conflicts developed between the contractor and subcontractor.

-Tracking waste once it was removed from the site, and verifying the status of the waste.

The "unconsolidated wastes" are to be characterized and disposed through a Bureau of Reclamation issued construction contract. The Small Business Administration requested the work to be set aside for a minority contractor. The onsite mobilization by the minority contractor began this April, and the removal work is scheduled for completion in July of 1994.

Issues encountered to date included:

-Unwillingness of landfills and salvage companies to accept wastes without characterization data.

-Defining the methodologies of waste characterization necessary to verify that these extremely heterogeneous wastes are nonhazardous.

-Obtaining the level of bonding required when the contractor is a small, minority business.

-Obtaining solicitor approval for multi-year contracting.

-Coordinating the review of all work plans with Ohio Environmental Protection Agency.

Timely Actions and Close Interagency Coordination to Expedite PRP Identification and Site Clean-up

MORAN, Mike, Bureau of Land Management, P.O. Box 26569, 4769 Vegas Drive, Las Vegas, NV 89126; SKINNER, Susan L., Bureau of Land Management, P.O. Box 12000, 850 Harvard Way, Reno, NV 89520

The establishment of an interagency environmental enforcement group facilitates timely cooperative efforts in times of crisis. This case study will cover why cooperative interagency efforts are important during emergency cleanups when illegal dumping has occurred. Specifically, the use of investigative efforts by the FBI and of the cooperative efforts of the media, when time is of the essence, may often result in the public helping identify potential responsible parties.

The Apex incident of Spring 1992 involved 300 containers that had been illegally dumped near a dry wash and on top of a desert tortoise burrow. In addition, the containers had recently been shot with automatic weapons which caused a release of hazardous substances from the containers. The weather was forecast for rain and a pre-race media drive through near the site was scheduled the next day for a cross-country off road race.

Responsive media involvement included the dissemination of reward information and a hotline number which lead to an individual coming forward with vital label information. A PRP was identified from this lead and the Bureau of Land Mangement was reimbursed for the initial emergency response. A total of $120,000 for clean-up and disposal expenses were paid by the PRP and further investigations are pending.

INNOVATIVE APPROACH TO PRP SITE CLEANUP AND BIOREMEDIATION AT THE REEDER AIRSTRIP

SERONKO, Paul J., Bureau of Land Management, Boise District
Office, 3948 Development Av., Boise, Idaho 83705

Two innovative approaches for clean up were utilized at a contaminated airstrip on public lands near Twin Falls, Idaho. The first was the use of a promissory note for PRP reimbursement to the Bureau for removal actions taken at the site. The second was a cooperative research project with the University of Idaho's Center for Hazardous Waste Remediation Research utilizing bioremediation to reduce contaminant levels in soil to below regulatory levels.

When the PRP could not afford to pay for corrective action at this site without impacting their existing business viability the Bureau stepped in and completed the corrective actions. A promissory note was used so the PRP could reimburse the Bureau for these actions over the course of a five year period thereby not affecting the status of the PRP's business.

A anaerobic consortium treatment technique was successfully utilized at this site for soils contaminated by the pesticide dinoseb (nitroaromatic compound). This research is part of EPA's Emerging Technologies program and will aid in cost effective remediation at such sites when land ban restrictions are in effect for these contaminants.

Krejci Dumpsite Coordination with Federal, State, & Local Entities

Fisher, Richard R., Environmental Engineer, National Park Service,
1709 Jackson Street, Omaha, NE 68102

When Congress established Cuyahoga Valley National Recreation Area in 1974, the NPS started condemnation proceedings to acquire land within the boundary of the park. In 1980, Cuyahoga Valley NRA started condemnation proceedings for the Krejci property for $1.4 million. In 1980, Congress also passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as the Superfund law. It was not until late 1985 that the park took title to the property and that actual site investigations could be performed. Soon thereafter, staff at the park became aware that there might be problems at the site when rangers began complaining about rashes, headaches and nausea, and a bottle collector rummaging through the site became dizzy.

It was at this point that the cleanup coordination began. To determine the extent of the problem, the park contacted the Environmental Protection Agency. They mobilized an emergency response crew and in 1987, EPA officials ordered an emergency removal action to stabilize the site. During this process, the NPS entered into an Interagency Agreement with EPA to begin cleanup of the site.

Because of the restrictions associated with the Superfund emergency response actions (e.g., limitations of 1 year and $2 million), work by the EPA was terminated. Approximately 2,000 drums and 1,500 cubic yards of hazardous waste were staged for removal. The majority of the waste had not been characterized and there still remained an estimated 32,000 tons of unconsolidated trash and debris, which was suspected to be non-hazardous. Consequently, the NPS began looking at other government agencies who might have the expertise in hazardous waste with available opened-ended contracts so that work could continue.

The NPS held several meetings with both the COE and the BOR to determine who could continue the cleanup effort. Following these initial contacts, an Interagency Agreement was signed with the BOR to coordinate the remaining removal work and perform any studies necessary to close the site. To formally close the site, we entered into a Consent Order with the State of Ohio EPA in April of 1989. Ohio EPA assumed regulatory authority for the site by issuing this Consent Order to the NPS requiring the NPS to perform an RI/FS of the site. After the RI/FS has been completed and we obtain a Record of Decision, an additional Consent Order with the Ohio EPA will be negotiated for the final cleanup alternative.

Throughout the entire cleanup effort, meetings have been held with the local communities, emergency response people, law enforcement agencies, and the public to keep them informed of the status of this project.

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Brett Pit Landfill CERCLA Investigation and Closure - Coordination with EPA, Washington Department of Ecology and the Colville Confederated Tribes

McCLENDON, Monte L., U.S. Bureau of Reclamation, 1150 N. Curtis Rd., Boise ID 83706-1234, (208-378-5036)

A large amount of aggregate was required for the construction of Grand Coulee Dam in the 1930's. Brett Pit was created and then immediately turned into a convenient dump site for the project and local municipalities. In the late 1940's the dump site became a landfill and a dozer was placed there to cover the debris. Because waste products since 1966 have been entirely from the dam, the site is classified as an industrial landfill and is not regulated under EPA's subtitle D rules for municipal landfills. Possible contaminants in the landfill included solvents, PCBs, pesticides and heavy metals.

The site was listed on EPA's Federal Facilities Docket which started the necessary Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) investigations. A magnetic and geophysical survey was used to identify the location of buried debris and detail the underlying strata. Five monitoring wells were installed around the perimeter and found no groundwater or any signs of contamination.

EPA scored the site under their hazard ranking system and issued a No Further Remedial Action Planned (NFRAP) decision. The Washington Department of Ecology (WDOE) assumed jurisdiction of the site under their Model Toxics Control Act. Although there were no pathways for contamination to reach the public, (WDOE) ranked the site a "1" which is considered the highest level of concern. They demanded excavations into the waste. WDOE's regional office in Yakima, Washington refused to negotiate on the matter.

Because the land is within the Colville Confederated Tribes Indian Reservation, Reclamation requested the jurisdiction of the matter be solely with the Tribe. The Tribe expressed their right of self determination on their Reservation and asked EPA to order the state to relinquish their claim to jurisdiction. WDOE eventually conceded to the Tribal request. Reclamation then negotiated a cooperative agreement with the Tribe for proper closure of the site. In November 1992, the landfill was closed. Under terms of the agreement, Reclamation will cover and shape the landfill as to prevent ponding and run-on. The Tribe will cap the site with clay and topsoil, reseed the area, plant yearling bitterbrush plants, and monitor the soil gas in the wells for 5 years.

The process has proven the ability of Reclamation to negotiate a practical and cost effective closure for a site which is believed to contain hazardous waste but does not pose a threat to human health or the environment.

COOPERATIVE EFFORTS TO PREVENT ENVIRONMENTAL CONTAMINATION AND PLANNED REMEDIATION FOR SUMMITVILLE MINE

WHITLOCK, L. Clark, U.S. Bureau of Reclamation, Provo
Projects Office, Hazardous Waste Staff, P.O. Box 51338,
Provo, UT 84605-1338

On December 3, 1992, Summitville (Summitville) Consolidated Mining Company, Inc., announced it would file for Chapter 7 bankruptcy the following day. The State of Colorado notified the Environmental Protection Agency (EPA) of this decision and requested assistance from EPA's Emergency Response Branch to stabilize the mine site. Summitville's parent company, Galactic Resources, Inc., agreed to pay salaries through December 15, 1992, to prevent early release of contaminated and potentially damaging water to the Rio Grande River system. Following several interoffice meetings, Hays Griswold, the assigned onsite coordinator for EPA, contacted the Bureau of Reclamation's (Reclamation) Upper Colorado Regional Office in Salt Lake City, Utah, with a request for contracting help.

A limited time was available to put on site a work force which was qualified to operate the water treatment facilities at what had been one of the country's largest gold mines. Reclamation had an "indefinite quantities" contract with Environmental Chemical Corporation (ECC) to provide hazardous waste investigations and removal services. ECC was mobilized to this site and, with few minor modifications, has been able to lower the water levels in the Heap Leach Ponds to an elevation that prevents uncontrolled discharge. ECC started a technical assessment process, utilizing both inter-Governmental and industry experts, to plan for an early and successful conclusion to this potential disaster.

Reclamation's role of providing a contractor for this work in a timely manner helped to avert a potential disaster. Reclamation's presence at the mine provides technical expertise and assistance to the team effort necessary for this complex project.

LEGAL WORKSHOP - DOI ISSUES
MINING, INDIAN LANDS, PRPs

Discussion of Department Issues

Chaffin, John C., Solicitor's Office, Billings Field Office, P.O. Box 31394, Billings, MT 59107-1394

The Department of Interior faces several CERCLA\RCRA issues that are unique to the Department. The 1872 Mining Law, trust responsibilities for Indian lands (also ownership) and agencies being PRPs and natural resource trustees may prevent the Interior from easily applying EPA regulations and prior federal case law.

The Clark Fork Superfund NPL Sites complex contains impacted resources administered by BIA, FWS and NPS. Litigation documents name the BLM, USGS and BM as PRPs. Additionally, the EPA and the State of Montana have sought out the BOR, USGS and FWS as experts for contracting and operations.

Issues at Clark Fork include:

1. Liability by being an owner of real property (BLM).
2. Liability as an operator/manager during war (BM & USGS).
3. Application of 113g in the **Montana** v. **ARCO** natural resource damage lawsuit. Is negotiations a viable alternative?
4. Legal ramifications of Interior agencies contracting with EPA and Montana for technical work at Clark Fork.
5. Interior and Agriculture trust responsibilities as natural resource trustee for the Confederated Salish & Kootenai Tribes.
6. The role of Interior agencies as non-parties in litigation over natural resources where Interior is a co-trustee.
7. The interaction between SOL/OEA/Agencies and with Justice/EPA and other Departments.

Federal environmental regulation laws apply to Indian reservations. However, the role of EPA, BIA and states in assisting regulatory development and in enforcement is uncertain. At Rock Boys and Blackfeet, the EPA raised issues of ownership and management as part of its attempt to have BIA pay for clean-up. Another issue worthy of clarification is the role of BIA when tribes seek "treatment as states" with the EPA.

POSTER SESSIONS

POSTER SESSION:Currrent and Innovative
Spatial Technologies and Approaches

DIGITAL COLLECTION AND DISPLAY OF SURFACE ELECTROMAGNETIC DATA FROM LANDFILL SITES IN NORTH CAROLINA

BERG, Steven A. and CARDINELL Alex P., U.S. Geological Survey, 3916 Sunset Ridge Rd., Raleigh, North Carolina, 27607

Collection of digtital surface electromagnetic(EM) data and integration of these data with a geographic information system(GIS) combines two powerful technologies in hazardous waste site analysis. These methods provide technology for storing and processing large data sets, spatially defining the data within standard coordinate systems, and relating the data to known features within and around the area of study. Spatial displays of the instrument response over known buried features can also help with data interpretation.

Shallow frequency domain electromagnetic data were collected at several landfill investigation sites at Fort Bragg, North Carolina with a portable EM instrument(EM-31) connected to a data logger. Prior to data collection, an orthogonal grid was constructed and each grid intersection was marked with a flag. The grid intersections were surveyed and the grid corners were tied to a known coordinate location.

The orthogonal grid lines were traversed in a forward and reverse direction with the instrument and the data were collected at one second intervals, which resulted in a two to three foot spatial interval. As each grid intersection marker was passed, a digital marker point was added to the data file. Each line of data was uploaded to a computer, combined with other lines and assigned an x and y grid coordinate. A GIS point coverage was generated in grid coverage units(in these examples we use feet). This coverage was transformed using GIS software into a standard projection system(State Plane Coordinates) by projecting the corners of the constructed grid into the surveyed coordinates.

In previous studies, a 200 by 200 foot grid spacing usually resulted in a data set of 50 points or less. Digital data collection, which requires no more time than data collection for previous studies and can be completed by one individual, has increased the data set size and resolution by an order of magnitude. Lost and misplaced data has decreased because the data sets become part of larger spatial data bases. When an anomaly is found, the increased resolution allows quick and accurate spatial interpretation of the instrument response.

The data set can also be related to other digitized features within the study area because it has a standardized coordinate system. Several cultural features(overlays) have been digitized and the instrument response is plotted in relation to coverages of reinforced concrete slabs, buildings and roads, and elevation. When a buried feature has been identified from a GIS coverage, data collection over the known feature combined with the spatial display of the instrument response can aid future interpretations.

USGS/Branch of Geochemistry Geoanalytical Capabilities Related to Hazardous Materials and Environmental Contamination

Detra, D.E. and Gough, L.P., U.S. Geological Survey, Branch of Geochemistry, MS 973, Box 25046, Denver Federal Center, Lakewood, Colorado, 80225

The work of USGS scientists reflects the public's concern for responsible resource management and environmental stewardship. The Branch of Geochemistry conducts basic and applied science that is the basis for understanding environmental processes and produces information that is the basis for environmental management decision making.

The Analytical Chemistry Services Group (ACSG) of the Branch of Geochemistry has been at the forefront of analytical inorganic chemistry for the analysis of earth science materials for over four decades. The emphasis of the ACSG has been to develop and implement analytical technologies that enable Branch geochemists and environmental scientists to most effectively solve problems related to geochemical processes and rock-water interactions as they apply to environmental issues. The laboratories are staffed with over 60 chemists, research chemists and laboratory technicians, who routinely prepare and analyze over 40,000 earth-science materials annually for major, minor, trace, and ultra-trace inorganic constituents. Total- and partial-element determinations are made using a variety of instrumental techniques including: X-ray fluorescence spectrometry, X-ray diffraction, instrumental neutron-activation analysis, atomic-absorption spectrometry, ICP-AES, ICP-MS, and ion chromatography. Routine analytical techniques used by the laboratories have been validated by the Branch quality assurance staff who continually monitor data quality.

The Branch of Geochemistry initiated a standard reference materials (SRM) program in 1962 to develop reference materials which are relevant to the analysis of a variety of environmental and geologic sample media. As a result of this effort, Branch analysts have produced and chemically characterized 31 standard reference materials for domestic and international distribution. Of the 31 SRM's that have been produced, the Branch has prepared several on-site reference materials for environmental studies and currently uses these materials for inhouse QA/QC purposes. When these materials were created, total-element analysis in combination with selected extraction procedures to evaluate element availability in the secondary environment were emphasized. In addition to the production and characterization of USGS SRM's, the Branch has cooperated with the National Institute

of Standards and Technology (NIST) to develop and certify environmental SRM's. Cooperative efforts have included the development of sediments, sludge, fly ash, and contaminated soil reference materials.

Environmental research is designed to monitor, understand, and predict geochemical landscape patterns and processes in both natural and human-altered environments. Whether the processes being examined occur naturally, such as fluids moving through mineralized rock, or are the result of human activities, such as factory effluent moving through an aquifer low-temperature, geochemical principles can be applied to both.

Specifically, USGS environmental geochemistry research seeks to:

Monitor (describe) the geochemical environment. Studies focus on areas that are geochemically altered, either naturally (mineralized) or by human activities. A first step is to define geochemical baselines by using statistically based sampling methods and then use the results to determine how "different" the area is compared to other areas. Another use of this type of information is to establish data bases necessary for the assessment of future potential changes. For example, the degree of contamination of a coastal salt marsh that is receiving industrial metals can be determined today, and changes over time can then be monitored by repeating the study in the future.

Understand (interpret) existing environmental problems. This is accomplished by (a) studying how chemical elements are distributed in landscape materials by conducting broad-scale geochemical surveys, and (b) studying the processes by which major- and trace-elements are mobilized from landscape materials, transported through the environment, taken up by plants and animals, affect plant and animal nutrition and health, and ultimately deposited back in some geologic "sink". Recently, concern over selenium in aquatic wildlife refuges in the western U.S. developed because human irrigation activities enhanced the mobilization of this element from marine shales and concentrated it in field drain water that ultimately flowed into the refuges. In California's San Joaquin Valley, subsequent build-up of selenium through the aquatic food chain at the Kesterson Refuge resulted in selenium toxicity in wildlife.

Predict (model) environmental problems using information from multidisciplinary approaches. Drainage from abandoned mines in Colorado is currently being studied and categorized by geologic terrain. The goal is to predict the geochemical characteristics of drainage from new mines that may be proposed. This type of information will be useful in developing pre-mine plans that will save development costs and environmental degradation, and will lead to more appropriate methods of reclamation.

Creosote Contamination of the Sand-and-Gravel Aquifer near Pensacola, Florida

FRANKS, Bernard J., U.S. Geological Survey, 227 N. Bronough Street, Suite 3015, Tallahassee, FL 32301, GODSY, Edward M., U.S. Geological Survey, 345 Middlefield Road, Mail Stop 458, Menlo Park, CA 94025

Between 1902 and 1981, a wood-preserving plant near Pensacola discharge an estimated 500 gallons of wastewater per day into an unlined surface impoundment hydraulically connected with the sand-and-gravel aquifer. The wastewaters primarily included residual creosote, with lesser amounts of pentachlorophenol and diesel fuel from the pole treatment operations.

The surficial aquifer consists of deltaic, fine-to-coarse sand deposits, interrupted by discontinuous silts and clays which cause local confinement. Ground water in the vicinity of the site generally moves south toward Pensacola Bay. The local flow system south of the impoundment is complicated by a shallow, silty clay lens (thickening toward the south) which effectively divides the plume of contaminated ground water into two zones. Flow is further complicated by a small drainage ditch which intercepts shallow ground water in the upper zone and acts as a direct conduit for contaminants into Pensacola Bay. The contaminated zones are anaerobic, with high concentrations of dissolved organic carbon (>400 mg/L), methane (>20 mg/L), ammonia (>5 mg/L), and iron (>20 mg/L). Stable carbon isotopes show significant fractionation, with heaviest delta carbon-13 values immediately beneath the pounds.

The zones of contaminated ground water extend downward to about 100 feet beneath the impoundments and laterally to about 1,500 feet down- gradient, attenuating about 800 feet short of Pensacola Bay. Calculations of travel distances based on estimates of flow velocities substantiate that the organic contaminants are attenuated rapidly in the aquifer. Attenuation results from both physical and microbial processes. Physical processes include dilution, dispersion, and partial discharge of the contaminated ground water to a small drainage ditch which intercepts the shallow flow system. Microbial processes include degradation of selected compounds by methanogenic bacteria.

Soil Gas Sampling, Direct Push Testing and Water Sampling

GEMPERLINE, Mark C., KUNZER, Elizabeth A., SODERQUIST, John, FARRAR, Jeffrey A.and Howard A. SALMAN, Bureau Of Reclamation, Research and Laboratory Services Division, P.O. Box 25007, Denver, Colorado, 80225, (303)-236-4319.

As part of Reclamation's research in specialized geotechnical methods for site characterization we have recently acquired new sampling equipment for site characterization. A soil gas sampling and testing vehicle and a 20-ton cone penetrometer vehicle are available for hazardous waste site characterization needs of Reclamation and other agencies. Reclamation will be performing research on these emerging technologies and assisting with technology transfer. As part of Reclamation's research program on Environmental Geotechnology, applied research programs for these systems are being sought. Some studies are underway with other agencies such as the Corps of Engineers, and EPA's Environmental Systems Monitoring Laboratory. When schedules do not conflict, this equipment could be made available to other agencies to reduce exploration costs.

Soil gas sampling for volatile organic compounds is an effective screening method to delineate plumes at leaky tank or spill sites. The soil gas sampling vehicle consists of a Dodge pickup mounted with a Geoprobe 8-m hammer system and onboard laboratory with a Tracor 540 gas chromatograph. The gas chromatograph has both flame and photo-ionization detectors with computer control. The prime function of this equipment is to perform rapid soil gas surveys in the vadose zone by driving rods into the ground, exposing the tip, and applying vacumn to extract soil gas. The equipment is also capable of taking soil samples and water samples. Reclamation also can deploy a portable x-ray fluorescence analyzer for detection of metals from soil samples.

Reclamation was the first government agency to deploy a 20-ton electric cone penetrometer vehicle in the United States. We are now deploying specialized penetrometers for use in hazardous waste site characterization and are participating in applied research with other agencies. The electric cone penetrometer with piezometer sensor is well renowned in the geotechnical engineering field for it's exceptional ability to delineate site stratigraphy. Production is from two to ten times that of conventional drilling. The prime advantage over conventional drilling is that no contaminated cuttings are generated, the equipment is easy to decontaminate, and chances for cross contamination are minimized. Sand layers as thin as two to three inches can be detected and sampled. The piezo element on the cone penetrometer can take pressure measurements in aquifers and dissipation tests in aquitards to estimate insitu permeability for calibrating hydraulic models. Three forms of direct push discrete point water samplers are now available, BAT enviroprobe, hydropunch, and simple wellpoints. The BAT system can obtain a sealed water sample and perform pressure and hydraulic conductivity measurements over a screen length of 0.3 ft. The hydropunch and wellpoint samplers have screen lengths up to 4 ft. A resistivity penetrometer is also available to profile subsurface resistance and delineate contaminated zones.

New Technologies for Environmental Site Characterization

KING, T.V.V., PELLERIN L., SANDER, K., ELLEFSEN, K., HASBROUCK, B., HORTON, B., LABSON, V., NELSON, P., OLHOEFT, G.R., SMITH, B., STEWART, D., and WRIGHT, D.

Branch of Geophysics, U.S. Geological Survey, P.O. Box 25046 (Mail Stop 964), Denver CO 80225

The remediation of environmental problems requires detailed and accurate information on the character and extent of contamination. The collection of this information by non-invasive methods is preferred and often required to prevent the further spread of pollutants. While conventional geophysical techniques often provide the needed information, the nature of environmental pollution is so different from traditional geophysical targets that new and innovative approaches are required.

The Branch of Geophysics environmental and geotechnical unit has developed a wide range of innovative geophysical techniques explicitly for environmental site characterization. Some of these include : airborne resistivity mapping of brine contamination, a high-frequency electromagnetic sounder used to map organics in soil, time-domain and low induction number electromagnetics for aquifer definition, downhole logging and analysis techniques for DOE's Yucca Mountain project, ground penetrating radar including borehole and surface measurements to determine DNAPL migration, development of a a novel shear wave source to map fractures and disrupted ground, laboratory and field complex resistivity and infrared-spectroscopy investigations of clay-organic reactions, hole-to-hole radar and velocity tomography to determine physical properties in the volume of rocks between two wells, and development of a geophysical adviser expert system for helping select appropriate geophysical techniques for site characterization.

These technologies have been successfully applied to to environmental and ground-water investigations. Working with other Federal and state agencies, the Branch of Geophysics environmental and geotechnical unit focuses on improving traditional geophysical methods and developing new methods for environmental problems, thereby helping the USGS and its cooperators meet their programs goals. In addition, the Branch provides scientific expertise and technical services for integrated solutions to site specific characterization problems.

Bioremediation of Uranium- and Chromium-Contaminated Environments with Metal-Reducing Microorganisms

LOVLEY, Derek, R., PHILLIPS, Elizabeth, J. P., and LANDA, Edward, R.,
National Research Program, Water Resources Division, U. S.
Geological Survey, 430 National Center, Reston, VA 22092.

A novel biological technique for removing uranium from contaminated waters and soils has been developed. This method takes advantage of our recent finding that some microorganisms can use uranium in a manner that is analogous to the way in which most living organisms use oxygen. The microorganisms oxidize organic compounds to carbon dioxide with the concurrent reduction of the U(VI) to U(IV). U(VI) is highly soluble and is, therefore, mobile in most environments. In contrast, U(IV) is highly insoluble and relatively immobile. Thus, microbial uranium reduction can effectively immobilize uranium in situ in an aquifer or lagoon, or it can be used in a pump-and-treat process to remove uranium from contaminated waters. Microbial uranium reduction can also be used following a simple soil extraction to concentrate uranium from contaminated soils.

In laboratory studies, microbial uranium reduction has been shown to effectively remove uranium from several mine drainage waters on Department of Interior lands, and from ground water at a Department of Energy site. The technique of combining soil washing and microbial uranium reduction has successfully removed and concentrated uranium from Department of Defense and Environmental Protection Agency Superfund sites. Preliminary studies have suggested that a similar type of microbial metabolism can detoxify water contaminated with chromate by converting soluble, highly toxic, Cr(VI) to less toxic, less soluble Cr(III).

The results indicate that microbial metal reduction could be a useful technique for removing toxic metals from contaminated waters and soils on Department of Interior lands.

VISUALIZATION OF REAL-TIME HYDROLOGIC INFORMATION AT ROCKY MOUNTAIN ARSENAL USING THE GEOGRAPHIC INFORMATION SYSTEM (GIS)

Donald E. Schild and Clifford R. Bossong[1]

ABSTRACT

A system of computer programs called RTMAP (real-time mapping), written by Tim Liebermann, supervisory hydrologist, Carson City, NV, Janet C. Ciegler, computer specialist, Columbia, SC, and Susan Lambert, publication graphics specialist Columbia, SC was modified to provide visualization of real-time hydrologic information at Rocky Mountain Arsenal. The system of programs is written in Arc Macro Language[2] (AML) and Fortran, and provides interactive graphics display and query of hydrologic data from a comprehensive network of data collection platforms. Stations in the network transmit data to a satellite for relay to a local readout ground station (LRGS) connected to a Prime minicomputer utilizing the U.S. Geological Survey's Automated Data Processing System (ADAPS) which transfers data to Data General Aviion workstations at the Rocky Mountain Arsenal for display using the GIS software.

Hydrologic data sensed at each data collection platform are referenced by site of the sensor and parameter codes that correspond to stage, streamflow, precipitation, and water elevation. Threshold values can be entered into ADAPS so that the current value at the site can be flagged as extreme alert, alert, normal, or no data. The data can be processed and sent to the Data General workstations at the Rocky Mountain Arsenal every 15 minutes if needed. The interval of data transfer is controlled by the administrator of the program and can be set to intervals ranging from every 15 minutes to once a day. The data are processed and ready for display automatically with no user intervention once the interval has been established.

In addition to the alert status, new routines that facilitate graphic display of the most recent data value for any parameter have been developed. After, or before reviewing the current value, a time series graph of the current value and the values from the previous 5-day period can be drawn on the screen for a selected site and parameter code.

Many additional functions provide for hardcopy reports, interactive query for latitude and longitude, as well as the capability to execute arcplot, arc, and system commands. There are also several options available to investigate and study the available data and GIS covers such as pan and zoom, specification of background covers, and custom specification of drawing environment variables.

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[1] Hydrologists, U.S. Geological Survey, 7th & C Street, Bldg. Z-68, Commerce City, Colorado 80022.

[2] The use of firm and trade names in this abstract is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

SOCIETAL VALUE OF GEOLOGIC MAPS

David R. Soller, Branch of Eastern Regional Geology, Office of Regional Geology,
USGS, Reston, VA 22092
Richard L. Bernknopf, Office of Chief Geologist, USGS, Reston, VA 22092

ENVIRONMENTAL DECISION MAKING

Addressing environmental concerns presents decision makers with choices that have far-reaching societal implications. Economic development and land management decisions at all levels from local to global are influenced by their potential for causing environmental changes. Deciding to preserve certain tracts of land, for example, may limit economic opportunities and lessen or enhance the value of nearby lands. Conversely, inappropriate development may provide short-term benefits while creating long-term problems that could present future generations with extremely costly consequences. The U.S. Geological Survey (in USGS Circular 1111) has developed an economic model that combines earth science, engineering, and socioeconomic information in a geographic information system (GIS) to produce maps and databases useful for decisions that could have environmental consequences.

GEOLOGIC MAPS AND ENVIRONMENTAL RISK ANALYSIS

What impact can the application of geologic map information have in the process of environmental decision making? Geologic map information can provide input to an environmental decision. Geologic maps are relevant to environmental decision making because of the integral role they play in the evaluation of a societal risk. A model has been developed and applied to an actual environmental decision concerning siting a waste disposal facility in the eastern part of Loudoun County, Virginia on the western fringe of the Washington, D.C. metropolitan area.

Siting a waste disposal facility is a significant environmental and economic issue because of the potential shortage of available sites and the threat to water supplies from leakage of hazardous materials. There is a direct correlation between the rate of transport of dissolved and suspended contaminants away from a facility and the permeability, faulting, and fracturing of the surrounding geologic materials. Changes in shallow sub-surface conditions that reflect local variations in the geology near a disposal facility can affect both the rate of transport of contaminants and the areal extent of contamination.

To prepare the geologic map information for analysis (a) a geologic map (1:100,000 scale) of eastern Loudoun County was converted to digital format, (b) a digital derivative map of near surface permeability (as average ground-water yield in gallons/minute) was constructed from the digital geologic maps, and (c) the derivative map was "gridded". Gridding is a computerized process of placing a grid of rectangular cells over the map and calculating an area-weighted average ground-water yield per grid cell. This is done so that the geologic map data can be

treated quantitatively and combined with other gridded, digital information in a geographic information system (GIS) to perform the required statistical and regional economic analyses.

For each map, the analysis proceeded in a stepwise fashion as follows:

(1) The suitability of a grid cell(s) on the geologic map for a waste disposal facility was determined using hypothetical protocols/screens related to rock permeability (average yield).

(2) For each grid cell on the geologic map, a probability of contamination was estimated as a function of average yield.

(3) The monetary value of the property in each grid cell was estimated.

(4) For each cell identified as unsuitable for a waste disposal facility in step 1, the expected property losses avoided (savings) realized by not placing a facility in or near the cell was estimated as the product of the probability of a loss and the monetary value of the loss (total property value) in the cell.

A geologic map data base for the Nation will result in subtantial savings if properly applied to balanced land management decisions. The issue of whether all applications of geologic map information will yield positive societal value is unknown. However, in regions that exhibit economic growth, geologic maps will be increasingly important for making decisions on avoiding irreversible environmental impacts, mitigating effects of natural hazards, and revitalizing the Nation's infrastructure.

ABSTRACT
HAZMAT CONFERENCE

POSTER SESSIONS
Hazardous Waste Source Reduction
and Environmental Compliance Issues

WATER TREATMENT - REMOVING CONTAMINANTS OF CONCERN

JONE, Harry T., D-3130, Bureau of Reclamation, PO Box 25007, Denver Federal Center, Denver CO 80225, (303) 236-9096; JURENKA, Robert A., D-3130, Bureau of Reclamation, PO Box 25007, Denver Federal Center, Denver CO 80225, (303) 236-0397.

Groundwater and surface waters have been contaminated with toxic and hazardous materials through human activity for many decades, with little concern for the environment. These contaminants, including undesirable organic and synthetic organic products, often pose serious health risks, adversely affect the environment and render water resources unfit for use. If left unchecked, these contaminants migrate, reaching existing and potential future water supplies for agricultural and domestic use. The Environmental Protection Agency (EPA) has mandated that these contaminated waters be identified, the extent of contamination be determined, and the soil and water at affected sites be remediated to meet risk based remediation goals.

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) legislates a program to clean up hazardous waste sites. While CERCLA is directed to private enterprise, it applies equally to Government installations. However, the Hazardous Substance Superfund (Superfund) may not be used to remediate a Federally owned site. Each Federal agency is expected to budget through the normal process for remediation of their own contaminated sites.

The EPA has mandated that hazardous waste site owners, including Federal agencies, follow a rigorous procedure to identify, investigate and remediate hazardous waste sites. Both Removal Action (quick response) and Remedial Action (long term program to remediate and close a site) must be considered. Once identified, work plans and reports at each step of the process must be submitted for review and approval by State agencies and the EPA. Water and soil must be treated using the Best Available Technology, the contaminants collected, contained or neutralized, and the residual contaminants safely disposed.

The Bureau of Reclamation (Reclamation) has been assisting other Federal agencies (through the Economy Act of 1932, 31 U.S.C. 1535-1536), in meeting their obligations under CERCLA as well as remediating its own contaminated sites. Reclamation assistance includes developing work plans, conducting investigations,

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preparing reports, designing and constructing collection and treatment systems and in safely disposing of contaminants. It has also provided technical oversight assistance to EPA and other Federal agencies who are having the work done under contract through private enterprise.

Examples of projects completed using Reclamation's multi-discipline team approach are:

- Fairchild Air Force Base - An alternative water supply system to replace private wells which were contaminated by a nearby landfill.
- Leadville Mine Drainage Tunnel - A water treatment plant to remove heavy metals from mine drainage.
- Lidgerwood Water Treatment Plant - Modification of an existing municipal water treatment plant to lower arsenic, iron, and manganese to drinking water standards.
- Feasibility Study and On-site Testing - Well head treatment (desalting) of brackish water for municipal use.
- Odessa Chromium II Superfund Site - Technical oversight to EPA for chromium removal from contaminated groundwater.
- Warren Air Force Base - A pump and treat system for trichloroethylene removal from contaminated groundwater.
- Krejci Dump Site - Removal of contaminated and mixed solid wastes from a commercial dump.
- Warren Air Force Base - Feasibility studies for remediation of contaminated groundwater and soil at hazardous waste sites.
- West Basin Desalting Demonstration Project - Removal of dissolved solids, silica, barium, strontium and metals from groundwater using reverse osmosis.
- Yuma Desalting Plant - Removal of dissolved solids from agricultural drainage using reverse osmosis.

Reclamation can provide other Federal agencies with unique capabilities, including:

Conducting validation/treatability studies in the Reclamation laboratory.

Design and construction management services. A multi-discipline team is available including chemists, engineers, architects, microbiologists and geohydrologists.

The Federal presence needed for Federal contracting.

ASSESSMENT OF POLLUTANT TRANSPORT AND ACCUMULATION IN BOSTON HARBOR AND MASSACHUSETTS BAY

M.H. Bothner[1], B. Butman[1], J.C. Hathaway[1], H.L. Jenter[2], H.J. Knebel[1], F.T. Manheim[1], R.P. Signell[1], and M.B. ten Brink[1]

[1]U.S. Geological Survey, Branch of Atlantic Marine Geology,
Woods Hole, MA 02543
[2]U.S. Geological Survey, Water Resources Division, Reston, VA 22092

The USGS program in Boston Harbor and Massachusetts Bay is designed to describe the critical processes influencing the transport and accumulation of fine-grained sediments and their associated contaminants. It is important to understand these processes because of the long history of pollution in Boston Harbor and the plans to construct a major outfall for treated sewage effluent in western Massachusetts Bay. Our program includes: measurements of contaminant inventories and distributions; development of a contaminated-sediments data base; geologic mapping; measurements and modelling of currents; sediment transport observations; and measurements of sediment mixing and accumulation rates.

The USGS program is designed to answer fundamental questions such as:

- What are the present contaminant levels in the sediments and how will they change?

- Where do sediments and associated contaminants accumulate and at what rate?

- What is the texture and morphology of the sea floor environment in the harbor and bay?

- How are water and materials transported throughout the system?

The USGS effort complements and is closely coordinated with the research and monitoring studies supported by the EPA Bays Program, the Army Corps of Engineers, local universities, and other state and federal agencies.

Key results to date:

- A digital map of the seafloor morphology and texture has been created from maximum-coverage sidescan-sonar data calibrated with photographs and sediment analyses. The map helped in the selection of the specific outfall location, and identified sites of fine-grained sediments where pollutants are most likely to accumulate. These sites have been used for long-term monitoring of sediment contamination. A reconnaissance map showing regions of erosion and deposition also has been completed

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for most of Boston Harbor and Massachusetts Bay.

* A contaminated-sediments data base has been compiled for Boston Harbor and Massachusetts Bay in order to assess pollutant concentrations and inventories. Data from more than 1,700 sediment samples reveal that the concentrations of metals (copper, lead, cadmium, zinc, silver, nickel, chromium and others) in fine-grained sediments of Boston Harbor are higher than in natural, uncontaminated sediments. The most serious metal contamination in the harbor is caused by mercury; over 90% of the samples exceed the suggested National Oceanic and Atmospheric Administration criteria for low level toxicity. Preliminary results suggest that Zn, Cu, Hg, and Pb concentrations have decreased in Inner Harbor sediments since 1978, possibly in response to source reduction.

* Continuous measurements (1989-1993) of currents and sediment transport are being made near the location of the proposed ocean outfall to characterize transport processes, especially during infrequent storms. These long-term measurements show that long-period storm waves resuspend bottom sediments over much of western Massachusetts Bay. In winter, when the water column is mixed, particles are resuspended throughout most of the 30 m water column, providing a greater opportunity for particles to adsorb dissolved contaminants and transport them eventually to the bottom sediments. Bottom-dwelling organisms mix recently-deposited sediments and associated contaminants deeper into the sediment column, potentially sequestering them from further resuspension and transport.

* More than 3 years of current measurements made near the new outfall site suggest that water and material discharged there are not swept away in a consistent direction by a well-defined steady current but are mixed and transported by a variety of processes, including the action of tides, winds, and river inflow. One-day particle excursions are typically less than 10 km. The outfall is apparently located in a region to the west of the basin-wide residual flow pattern.

* A numerical model of currents in Boston Harbor and Massachusetts Bay generated by this project has been extremely useful for comparing the existing discharge location and the new outfall location with respect to areas impacted by sewage effluent. The visual display of the computer-generated data has aided the exchange of information to decision makers and to the public. The results show that because of greater initial mixing at a deeper site, the new outfall location will improve water quality in the harbor and will not appreciably change water quality in the bay compared to the present discharge location.

SITE DISCOVERY, INVESTIGATION, AND REMEDIATION

Geochemical and Hydrologic Characterization of Acidic Mine Contamination in Pinal Creek Basin, Arizona

BROWN, James G., U.S. Geological Survey (USGS), 375 S. Euclid Ave., Tucson AZ 85719, STOLLENWERK, Kenneth G., USGS, MS 415, Box 25046 Federal Center, Denver, CO 80225, GLYNN, Pierre D., USGS, National Center, MS 432, 12201 Sunrise Valley Drive., Reston, VA 22092

The Pinal Creek basin is in central Arizona about 100 km east of Phoenix. Copper has been mined in the basin since 1882, first in underground mines and then in open-pit mines beginning in 1948. Acid-mine drainage has resulted from oxidation of sulfide minerals, ore processing, and other mining activities in the basin. Leakage from unlined surface-water impoundments is the likely principal source of contamination. Contamination has generated a 15-kilometer-long plume of acidic ground water in the alluvium of Miami Wash and lower Pinal Creek. In May 1992, dissolved-iron concentrations in the core of the plume were as large as 740 mg/L; pH was as low as 3.6.

Acidic ground water in the Pinal Creek basin is neutralized by bicarbonate, which occurs naturally in ground water in the basin, and by carbonate minerals. Oxidation and reduction reactions involve principally iron and manganese. Subsurface colloid transport was found to be unimportant in the acidic core of the contaminant plume, according to R.W. Puls and others (1991, USGS Water-Resources Investigations Report 91-4034, p. 507-510). Neutralized, contaminated ground water discharges to the surface in a perennial reach at the downstream end of the basin. Gas exchange between surface water and atmosphere causes carbon dioxide to decrease and dissolved oxygen to increase in the surface water. In the process, pH rises from about 7 to 8 and results in the precipitation on the streambed of manganese oxide minerals composed primarily of $(Ca,Mn,Mg)CO_3$ and a mixture of rancieite $((Ca,Mn)Mn_4O_9 \cdot H_2O)$ and takanelite $((Mn, Ca)Mn_4O_9 \cdot H_2O)$ (Lind and Hem, 1993, Applied Geochem., v. 8, p. 67-80). Manganese oxide crusts are primary scavengers of trace metals but provide only a temporary sink for contaminants because large flows break up some of the crusts and transport them out of the basin.

Reactions between acidic ground water and alluvium were first evaluated in laboratory column experiments. Data from these experiments were used to develop and calibrate a geochemical model capable of describing the observed changes in solute concentration. The equilibrium speciation program, MINTEQA2, was used to simulate the breakthrough curves for different constituents from the column. The diffuse-layer surface-complexation model in MINTEQA2 was then used to simulate the observed changes in concentration of aqueous constituents in the aquifer. Equilibrium constants for the surface-complexation reactions were obtained from the laboratory column breakthrough curves.

These equilibrium constants were then used to simulate the distribution of these metals along a one-dimensional flow path in the aquifer and perennial reach. Observed concentrations of copper, cobalt, and zinc decreased from more than 10,000 µg/L to less than 10 µg/L along the flowpath. Nickel decreased from 3,500 µg/L to less than 500 µg/L, and pH increased from less than 3.5 to about 8 over the same distance. The simulated pH-dependent sorption of these metals to oxide minerals using the diffuse-layer model accurately reproduced the observed downgradient concentration trends.

In collateral work, the speciation of elements in ground water at Pinal Creek was simulated by K.J.Novo-Gradac and C.N. Smith (1991, USGS Water-Resources Investigations Report 91-4034, p. 498-501) using a modified version of MINTEQA2. The model accounted for calcite dissolution and contaminant adsorption to aquifer sediments but did not allow for oxidation-reduction reactions. Using a modified code, the transport of 80 pore volumes of acidic water through a 50-cell "column" of carbonaceous aquifer material was simulated. Simulated pH correlated well with the solubility of ferrous iron. Simulated concentrations of soluble iron varied inversely with pH. Simulated concentrations of sorbed iron became significant when simulated pH rose from less than 3 to 5.6. Both phases decreased to zero as simulated pH rose from 5.6 to 6.8. Simulated concentrations of soluble, sorbed, and precipitated cadmium varied little and were all less than $10^{-5.3}$ mol/kg in cells in which pH was 5.6 or lower. All three phases increased abruptly to between $10^{-4.7}$ and $10^{-4.3}$ mol/kg at the point at which pH increased from 5.6 to 6.8. All decreased abruptly to zero when pH rose to and remained near 7.

Pinal Creek is one of several sites in the country at which the concentrations of chlorofluorohydrocarbons (CFC's) in ground water are being used to estimate time since recharge. CFC's, widely used as refrigerants and aerosol propellants, are useful in dating ground waters that recharged since 1936. Concentrations of CFC's in the atmosphere have risen steadily since CFC's came into widespread use in the 1930's. Partly because of this steady increase, CFC's are a potentially useful indicator of ground-water age.

Ground water in the basin was analyzed for CFC-11 and CFC-12. Ground-water ages estimated from CFC-12 concentrations were consistently younger than ages estimated from CFC-11 concentrations. For this reason, it is likely that ground water in at least part of the basin may have been contaminated with CFC-12. Preliminary results using CFC-11 indicate that ground water from a depth of about 18 to 27 m in alluvium upgradient from contamination sources was recharged in 1979. Uncontaminated water from shallow basin fill that underlies alluvium along lower Pinal Creek contained CFC-11 concentrations that were just above detection limits. If no mixing has occurred, this water was estimated to have recharged in 1945.

Selenium in the San Joaquin Valley; Hydrology versus Mythology

DEVEREL, Steven J., U.S. Geological Survey, 2800 Cottage Way, Room W-2233,
Sacramento, California 95825

Agricultural drainage problems in the San Joaquin Valley, California, have attracted national attention since 1983, when selenium in water from subsurface drainage systems in the central part of the western valley was found to have toxic effects on waterfowl at Kesterson Reservoir. About 1,000 migratory birds died (adults, embryos, and chicks) or were seriously malformed from 1983 to 1985 because of selenium toxicosis. Wastewater at Kesterson was classified as hazardous waste under two California State regulations in February 1985, and drainwater flows to Kesterson were eliminated in June 1986. Subsurface drainwater first started flowing from the western San Joaquin Valley to Kesterson Reservoir in 1978.

Prior to the conduct of hydrologic studies, misconceptions and myths about ground-water flow, the origin of selenium, and solute movement in the western San Joaquin Valley prevented the development of effective water-management plans aimed at mitigating the problem. Four myths were as follows: (1) The regional ground-water system was the primary source of high concentrations of selenium in drainage water; (2) high selenium water flowing to agricultural drainage systems is primarily through a shallow perched ground-water system underlain by impermeable layers; (3) high selenium concentrations were confined to the upper perched ground-water system within 50 feet of land surface; (4) coarse-grained subsurface alluvial channels were the primary conduit for ground water in the western valley and resulted in rapid ground-water flow rates from upper elevations of the alluvial fans to drainage systems at lower elevations.

Hydrologic studies conducted from 1984 through 1991 provided information about processes affecting movement and distribution of selenium, and ground-water flow that dispelled these myths. The hydrologic studies were conducted at local, regional, and subregional scales of observation. Results from local- and regional-scale studies showed that high concentrations of selenium in the drainage water originated from leaching of soil salts and subsequent evapoconcentration of shallow ground water. Studies at the local scale demonstrated that ground water flowing to agricultural drainage systems is a mixture of deep and shallow ground water. Drainage systems interacted with the regional ground-water flow system and no perched ground water was identified. Ground-water samples collected as deep as 140 feet below the water table had high selenium concentrations that were probably the result of leaching of agricultural soils.

Regional and subregional studies of the ground-water system demonstrated the presence of coarse-grained paleochannels. However, ground-water flow in these channels was not as rapid (tens of feet per day) as was previously thought. Flow rates were on the order of several tens of feet per year. Regional and subregional ground-water flow modeling aided in understanding the potential effects of water-management alternatives aimed at reducing selenium loads in drainage water. The results of model simulations indicated that if pumpage from existing wells were increased 0.5-1.5 feet per year and recharge rates were decreased 15 percent, the amount of drainage water and land needing drainage in the western valley would be reduced substantially.

Reclamation's Technical Assistance to EPA - Iron Mountain Mine Superfund Site

DOEBBLER, Krista A., U.S. Bureau of Reclamation, Mid-Pacific Region, 2800 Cottage Way, Sacramento CA 95825

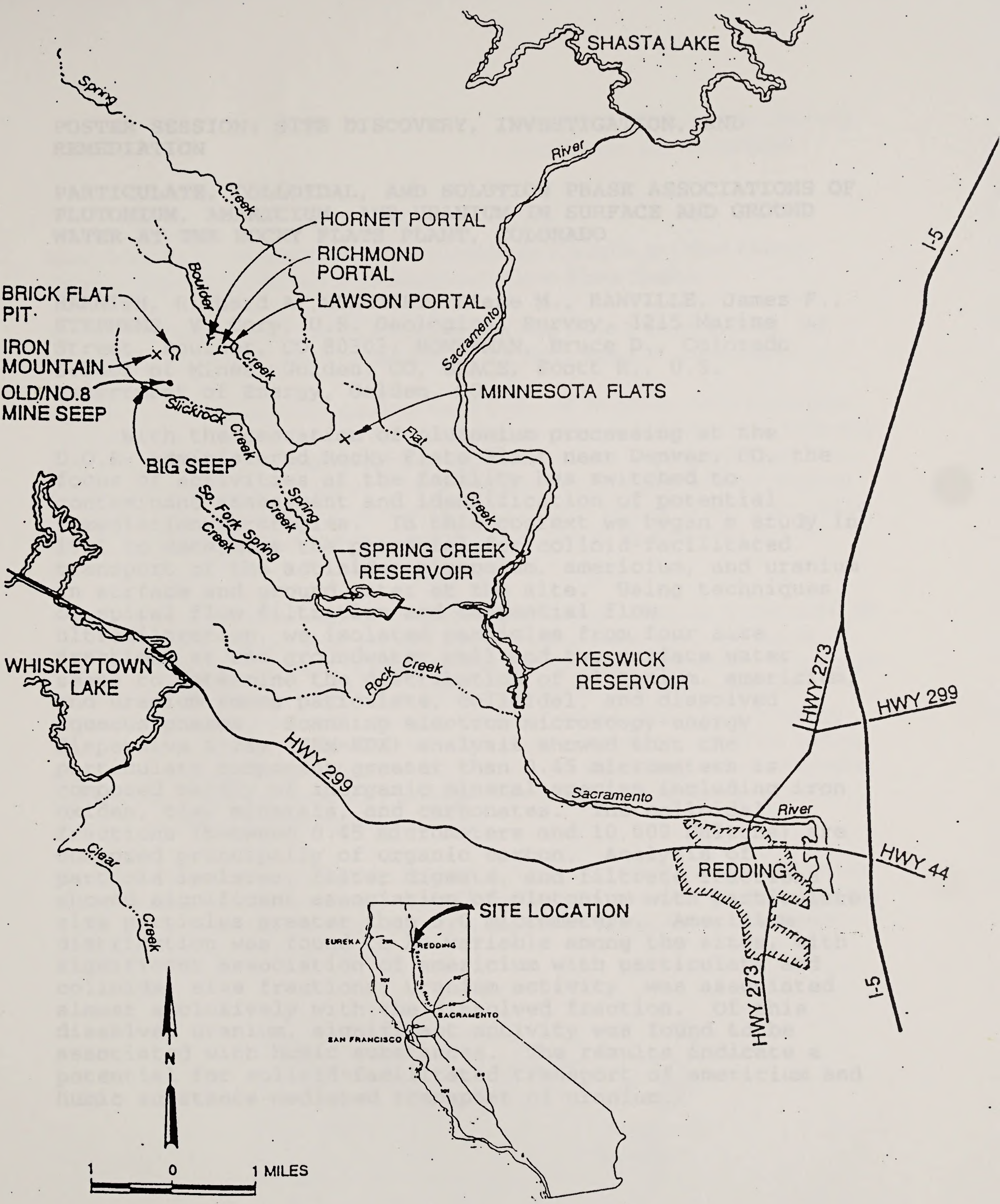
The Iron Mountain Mine Superfund Site (IMM), located near Redding, CA, was placed on the National Priority List by the U.S. Environmental Protection Agency (EPA) in 1983. IMM discharges approximately one ton of heavy metals (primarily copper, cadmium and zinc), in the form of acid mine drainage (AMD), into the Sacramento River, everyday. On October 3, 1986, EPA signed the first Record of Decision for the Site, selecting a specific interim remedial action cleanup plan for IMM.

The U.S. Bureau of Reclamation (Reclamation) has been assisting EPA, Region 9, in their Remedial Design/Remedial Action work at the IMM Site since 1988. Through a series of Interagency Agreements totaling approximately $6 million, Reclamation has performed the following tasks for EPA: designed and constructed the Slickrock Creek Diversion; designed and performed construction oversite of the Upper Spring Creek Diversion; designed the South Fork Spring Creek Diversion; and assisted EPA with cultural resource activities, domestic water supply relocation, public relations, design review, and construction management. In addition, Reclamation serves as a member of EPA's technical advisory committee.

The Slickrock Creek Diversion transports uncontaminated water from the creek, around a huge tailings slide, via a concrete conduit. The water is discharged back into the creek downstream of the slide. The Upper Spring Creek and Southfork Spring Creek Diversions route uncontaminated creek flows around Spring Creek Reservoir. This results in fewer uncontrolled releases of AMD from the Spring Creek Debris Dam.

Reclamation's Denver Office is currently designing the enlargement of the Spring Creek Debris Dam for EPA. The Dam was originally constructed by Reclamation in 1963, for the dual purposes of 1) controlling acid mine drainage entering the Sacramento River from IMM, and 2) preventing eroded soil (resulting from extensive deforestation caused by a copper smelter located at the Site around the turn of the century) from interfering with the tailrace of the Spring Creek Powerplant. EPA originally selected the enlargement of the Dam as one component of the Remedial Action cleanup in its' 1986 Record of Decision.

Reclamation is also performing construction management and oversite for EPA on the 600 gallon per minute AMD treatment plant being constructed by the Potentially Responsible Party.



IRON MOUNTAIN MINE

POSTER SESSION: SITE DISCOVERY, INVESTIGATION, AND REMEDIATION

PARTICULATE, COLLOIDAL, AND SOLUTION PHASE ASSOCIATIONS OF PLUTONIUM, AMERICIUM, AND URANIUM IN SURFACE AND GROUND WATER AT THE ROCKY FLATS PLANT, COLORADO

HARNISH, Richard A.,MCKNIGHT, Diane M., RANVILLE, James F., STEPHENS, V. Cory, U.S. Geological Survey, 3215 Marine Street, Boulder, CO 80303; HONEYMAN, Bruce D., Colorado School of Mines, Golden, CO, GRACE, Scott R., U.S. Department of Energy, Golden, CO

With the cessation of plutonium processing at the D.O.E- administered Rocky Flats Plant near Denver, CO, the focus of activities at the facility has switched to contaminant assessment and identification of potential remediation strategies. In this context we began a study in 1991 to determine the potential for colloid-facilitated transport of the actinides plutonium, americium, and uranium in surface and ground water at the site. Using techniques of spiral flow filtration and tangential flow ultrafiltration, we isolated particles from four size fractions at one groundwater well and two surface water seeps to determine the distribution of plutonium, americium, and uranium among paticulate, colloidal, and dissolved aqueous phases. Scanning electron microscopy-energy dispersive X-ray (SEM-EDX) analysis showed that the particulate component greater than 0.45 micrometers is composed mainly of inorganic mineral species including iron oxides, clay minerals, and carbonates. The colloidal fractions (between 0.45 micrometers and 10,000 Daltons) are composed principally of organic carbon. Analysis of particle isolates, filter digests, and filtrate fractions showed significant association of plutonium with particulate size particles greater than 5.0 micrometers. Americium distribution was found to be variable among the sites, with significant association of americium with particulate and colloidal size fractions. Uranium activity was associated almost exclusively with the dissolved fraction. Of this dissolved uranium, significant activity was found to be associated with humic substances. The results indicate a potential for colloid-facilitated transport of americium and humic substance-mediated transport of uranium.

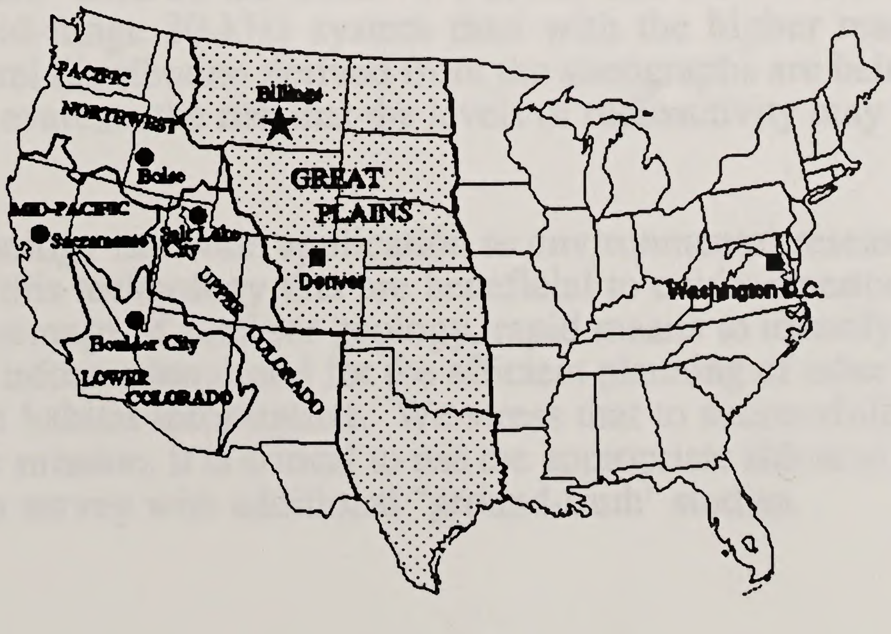
Hazardous Waste Technical Assistance Capabilities Available to Other Federal Agencies through the Bureau of Reclamation's Great Plains Region

JEWELL, Daniel E., U.S. Bureau of Reclamation, 316 N. 26th Street, Billings, MT 59101; LOOMIS, Dean, same address; MICHEL, Roger P., same address

The Bureau of Reclamation's Hazardous Waste Technical Assistance (HWTA) program was initiated in 1987 to provide technical assistance to other Federal entities in addressing their hazardous waste cleanup/management needs. Assistance is provided through site-specific Interagency Agreements on a 100% cost reimbursable basis. Overall program management and coordination is provided by Reclamation's Denver Office, while project specific coordination and management is provided by each of Reclamation's five (5) regions.

Reclamation's Great Plains Region, headquartered in Billings, Montana, is responsible for administering the agency's programs throughout Montana, North and South Dakota, Wyoming, Colorado, Nebraska, Kansas, Oklahoma, and Texas. The Great Plains Region has technical capabilities available in a variety of categories including: potentially responsible party searches, public relations, site investigations, surveying & mapping, underground storage tanks, waste minimization, property evaluations, feasibility studies, natural resource assessments, remedial design/action, site monitoring, and overall project management. Technical services are available either in-house or through a variety of qualified, indefinite quantity contractors.

The Great Plains Region is currently involved at twenty (20) active hazardous waste sites through interagency agreements with three (3) Federal agencies. To date, work has been completed on approximately twenty-eight (28) interagency agreements at sites located throughout the nine (9) state region.



Seafloor Mapping and Characterization: Application of Innovative Technologies to Environmental Management

KARL, Herman A., Chin, John L., both at U.S. Geological Survey, MS-999, 345 Middlefield Road, Menlo Park, CA 94025, Schwab, William C., U.S. Geological Survey, Quisset Campus, Woods Hole, MA 02543

Acoustic mapping coupled with sediment samples and photographs of the seafloor provides information about: (1) geology and geological processes, (2) biological habitats and ecological niches, (3) issues of environmental management, (4) issues of economic importance, (5) issues of public safety. A major goal of the study described herein is the transfer of the techniques and technology of basic marine research to applications in environmental management. To accomplish this goal, USGS formed partnerhsips with other federal agencies and private industry to obtain the best scientific information and to communicate this information in a timely way to scientists, and the public and those charged with management decisions concerning multiple use of offshore areas. The value of seafloor mapping is illustrated for the San Francisco Bay area where the environmental and ecological concerns of the Gulf of the Farallones National Marine Sanctuary must be reconciled with the human, economic and industrial demands of a major urban population center.

More than 47,800 drums (55 gallon) and other containers of low-level radioactive waste were dumped on the continental margin offshore of San Francisco Bay between 1946 and 1970. These drums now litter a large area (1200 km^2) of the sea floor within the Gulf of the Farallones National Marine Sanctuary. The exact location of the drums and the potential hazard the drums pose to the environment are unknown. To evaluate the risk, samples of the sediment, biota, and water must be collected near the concentrations of barrels. However, the exact location of the barrels must be known prior to sampling. The USGS, through a cooperative research agreement with NOAA, used sidescan sonar to map two areas within the sanctuary. Total sea-floor coverage was obtained and computer-processed sonographic mosaics were constructed on board ship. Many small nongeologic targets were distributed throughout the survey areas that covered about 70 km^2 on the shelf and 125 km^2 on the slope. Analysis of the sidescan data suggests that the targets are 55-gallon drums. This interpretation was confirmed at one site with an underwater video and 35-mm camera system. Data were collected with both a 30-kHz and a 120-kHz sidescan system within a 15-km^2 area on the shelf. We found that the barrels were more easily detected with the mid-range 30-kHz system than with the higher resolution 120-kHz system. Maps of barrel distribution derived from the sonographs are being used to design sampling schemes to evaluate the risk that the levels of radioactivity may have on the biota and environment.

Sidescan sonar technology has wide application to environmental research in the oceans. Derived products of this technology that are beneficial to environmental researchers and managers include basemaps of seafloor geology, rapid means to identify targets and their distribution, baseline information useful for the efficient planning of other studies and long-term monitoring, and habitat information. We stress that to successfully accomplish the goals of the particular mission, it is critical to use the appropriate sidescan sonar system and to follow the sidescan survey with additional "ground-truth" studies.

Applications of Environmental Geoscience Studies to the Identification and Remediation of Mining-related Hazardous Waste Sites on Public Lands

PLUMLEE, Geoffrey S., SMITH, Kathleen S., and FICKLIN, Walter H., U. S. Geological Survey, MS 973 Denver Federal Center, Denver, CO 80225

Ongoing research in the U.S. Geological Survey Office of Mineral Resources (USGS/OMR) is characterizing how geologic and geochemical factors control the environmental behavior of mineral deposits and mineral processing byproducts. These studies provide crucial environmental geoscience information needed (1) to make balanced land-use decisions, and (2) to help identify, prioritize the study of, and guide the remediation of hazardous mining sites on public lands.

For example, we are currently developing geologically-based environmental models of mineral deposit types. These models identify, for given mineral deposit types, the likely environmental signatures present prior to mining and resulting from mining and mineral processing; important parameters considered include the suites, concentration ranges, residences, and mobilities of heavy metals and other toxic elements in soils, sediments, ground and surface waters, mine waters and wastes, and mineral processing waters and wastes. By defining baseline environmental conditions for specific deposit types prior to mining, the models can be used to help establish geologically- and geochemically-valid remediation standards for these deposit types; this task has previously been quite difficult in historic mining districts where extensive mining activity masked pre-mining environmental conditions. The environmental models are also being incorporated into USGS/OMR mineral resource appraisals of public lands, so that the potential environmental effects resulting from the development of mineral resources contained in the lands can be better estimated. Finally, the models can be used in conjunction with USGS databases (such as the Mineral Resource Data System [MRDS] or the National Geochemical Database) and remote sensing techniques to help identify and estimate the possible environmental effects emanating from hazardous waste sites on public lands.

Process-oriented geochemical research has also provided significant insights into the geochemical processes that control metal transport, mobility into, and attenuation by the environment. For example USGS/OMR studies show that sorption by suspended hydrous iron oxide sediments in mine-drainage streams can effectively remove many heavy metals and other toxic elements from the drainage waters; as a result, natural sorption processes could be utilized in low-cost mine-drainage remediation schemes at some mining sites.

CLEANUP SUCCESSES

RICH, R. Wayne, U.S. Bureau of Reclamation, Provo Projects Office, Hazardous Waste Staff, P.O. Box 51338, Provo, UT 84065-1338; WHITLOCK, L. Clark, Hazardous Waste Staff; MEUNIER, Thomas E., Assistant Projects Manager.

Cleanup successes displayed in this poster session include such projects as the Remedial Design and planned Remedial Action at Sharon Steel/Midvale Tailings Operable Unit Two (in Midvale, UT), Bingham Creek residential cleanup (near Salt Lake City, UT), operation and planned cleanup at Summitville Mine (near Del Norte, CO), Olson/Neihart Tailings removal (from Jordanelle Reservoir near Heber City, UT), Sharon Steel Demolition (a smelter building in Midvale, UT), preliminary cleanup at Jacks Creek Campground in Pecos National Forest (near Pecos, NM), and various other projects which are currently under remedial investigations.

The display includes color photographs of the above referenced projects. These photographs show major activities and are captioned with details pertinent to investigations, designs, field work, and cleanup. Also displayed are samples of studies, documents, technical specifications, and drawings used in cleanup or planned cleanup. A documentary video showing residential cleanup at the Bingham Creek project is also available for viewing. This video shows the planning, design, and construction activities of the project.

Remedial Investigation of Landfill Sites

WADDELL, Kidd M., U.S. Geological Survey, 1745 West 1700 South, Salt Lake City, Utah, 84104

During July 1988-92, the U.S. Geological Survey did a Remedial Investigation (RI) of contamination at Operable Unit 4 (OU 4), at Hill Air Force Base (AFB), Utah. Laboratory analyses of water samples detected 13 volatile organic and 2 inorganic contaminants in the shallow ground water in the area of OU 4. Trichloroethylene (TCE) was detected most frequently and in the highest concentrations, with a maximum concentration of 18,000 ug/L. The total volume of TCE in the saturated and unsaturated zones was computed to be equivalent to 353 gallons of pure TCE product, or about 6 drums. Landfill 1, one of two landfills at OU4, was determined to be the most probable source of TCE.

The objectives of the RI were to: 1. Characterize the nature and extent of contamination; 2. Determine the source(s) and fate of contaminants; 3. Develop a baseline risk assessment for the potential exposure pathways through soil, ground water, and air. (James M. Montgomery, Consulting Engineers, Inc. conducted the risk assessment studies working under a contract with Hill AFB.)

OU 4 overlies the Sunset and Delta aquifers, which are productive sources of drinking water and are used by both Hill AFB and surrounding communities. Water in the Sunset and Delta aquifers generally is confined and occurs at depths of 300 and 600 ft below the landfills, respectively. Shallow ground water, in which contamination has been detected, overlies the Sunset and Delta aquifers.

Most of the sediments of the shallow ground-water system consist of clays and fine silt. Most ground-water movement near the landfills is in interfingered layers of sand and silt in the upper 30 to 60 ft of sediments. Orientation of the clay, silt, and sand layers in the shallow ground-water system is usually horizontal. Although downward vertical hydraulic gradients predominate in the shallow ground-water system, the horizontal component of average linear velocity is about 3,000 to 7,000 times greater than the vertical component. As a result, there has been no vertical percolation of contaminants to deeper aquifers.

Risk data available as of November 1991 (as determined by James M. Montgomery, Consulting Eng.) indicated that there were not any complete exposure pathways that presented any significant health risk to people living or working in the vicinity of OU4; however, more data need to be collected to adequately determine the risk associated with inhaling indoor air. The data also indicated that there was little potential for ecological harm as a result of the contaminants present at OU4. Human health risk associated with the occurrence of TCE, however, could develop in the future.

Site Investigation and Remediation EPA Technical Assistance Lehigh Portland Cement Co. Site - Mason City, Iowa

WILTSHIRE, Richard L., U.S. Bureau of Reclamation, Denver Office, Code D-3620, PO Box 25007, Denver Federal Center, Denver, CO 80225

The Bureau of Reclamation's Denver Office has provided technical assistance to the Environmental Protection Agency (EPA) - Region VII, during the investigation, analysis, and remedial design phases on the Lehigh Portland Cement Company Site (site) in Mason City, Iowa. Working directly with EPA's Remedial Project Manager and through interagency agreements since 1989, the Denver Office's multi-disciplinary technical staff has assisted EPA in a variety of capacities, as described below, during the Remedial Investigation (RI), Feasibility Study (FS), and Remedial Design (RD) work by Lehigh Portland Cement Co. (Lehigh) and its contractors.

Lehigh owns and operates a portland cement processing facility at the site, which has been in operation since 1911. A by-product of the process, waste cement kiln dust (CKD) that may exceed one million tons, has been placed in exhausted limestone quarries and in piles around the site. The CKD reacts with surface and ground waters at the site, producing a highly corrosive pH of 13.0 units in the water.

At EPA's request in December 1989, the Denver Office assembled a small team, experienced in geotechnical and chemical engineering, geology, and hydro-geology. The first assignment was a technical review of Lehigh's draft Site Investigation Protocol, based on previously-completed site evaluations. Based on the review comments provided to EPA, Lehigh was directed to revise their site investigation plans, including the addition of some off-site monitoring wells located down gradient from contaminated ponds. In addition, we suggested that an adjacent quarried area given by Lehigh to the county for use as a park (nature center) appeared to have received waste CKD from Lehigh and should be included in the investigation effort, which was done.

After the site investigations were completed, the draft RI was reviewed by the Denver Office team. Again, based on the review comments submitted to EPA, the RI was revised and finalized by Lehigh. The RI concluded that the site's surface and ground waters were being "contaminated" by the CKD, with pH values as high as 12.5, were moving off-site, and required remediation. Further, the adjacent county park area did contain waste CKD, exposing the public to potentially harmful (highly corrosive) contact, and was also affecting the area's surface and ground waters, requiring remediation of the area.

Similarly, the draft FS on the site's remediation was reviewed by the Denver Office team and comments were provided to EPA. Working through EPA and with Lehigh, the FS was improved and finalized and appropriate remedial treatment alternatives were developed and evaluated. The basic remedial approach for this site was to isolate the waste CKD and prevent its interaction with any precipitation, surface, or ground waters, preferably with a permanent remedy. The selected remedial alternative includes the following: 1) consolidate the site's waste CKD at various locations, including that in the park, and covers each pile with an engineered clay cap; 2) collect and treat the water in site ponds until required water quality standards are achieved, followed by the permitted discharge into a nearby river; 3) control groundwater to prevent interaction with consolidated waste CKD, especially in the exhausted quarries; and 4) continue monitoring of site surface and ground waters.

The draft Scope of Work for Lehigh's Remedial Design and Remedial Action Work Plan for the site was reviewed and comments were again provided to EPA for the finalization of the document. The team's input regarding the design criteria for various remediation treatments was especially valuable. For example, the stability criteria for the side slopes of the capped CKD piles needed to account for the unusual geotechnical behavior of CKD as one of the slope materials. Further, the constructability of the pile and its cap had to be properly envisioned. Development of necessary engineering data on both CKD and the cap clay, such as shear strength and permeability, was advised. A meeting was conducted to resolve such concerns and was very productive in developing a mutually acceptable remedial design approach.

Construction of a test pad was proposed by Lehigh to develop data on the permeability and construction of the cap clay overlying the CKD. The draft plan for this test pad was reviewed and revised, in accordance with our comments provided to EPA. A geotechnical engineer from the Denver Office subsequently represented EPA at the site during the test pad's construction and the installation of two sealed double-ring infiltrometers on the pad for testing the clay's permeability. Test data from the two infiltrometers was reviewed by the engineer during the test and comments and recommendations were provided to EPA and Lehigh.

The design of remedial modifications for the site is now in progress. The Denver Office will continue to provide technical assistance to EPA during the RD and Remedial Action (RA) phases of the site work, which may include construction inspection services. The quality and cost effectiveness of the investigation, analysis, and design work performed for the Lehigh site have been significantly enhanced by the Denver Office's assistance. EPA is extremely happy with the results to date.

U.S. GEOLOGICAL SURVEY HAZARDOUS CHEMICAL SPILL TEAM

CIRCE*, Ronald, U.S. Geological Survey, 914 National Center, Reston Virginia 22092, Wayne Martin, U.S. Geological Survey, 953 National Center, Reston Virginia 22092 and Randall Orndorff, U.S. Geological Survey, 902 National Center, Reston Virginia 22092.

The development of an in-house hazardous chemical spill response team as part of an organization's Occupant Emergency Plan is becoming a standard throughout industry and Government. The effectiveness of such a team depends primarily on the quality, quantity and appropriateness of training that response personnel receive. The most common type of chemical emergency occurring within the U. S. Geological Survey is of a magnitude greater than the average laboratory worker can control yet of a size that a well trained and equipped in-house Hazardous Chemical Spill Team can readily manage.

The U.S. Geological Survey National Center Hazardous Chemical Spill Team was formed in 1982 as a result of an accident in a chemical stock room. This incident exposed the weakness of not having an organized plan for responding and managing chemical spills at the National Center. With over 3500 different chemicals and 167 chemical laboratories, the Spill Team was formed to handle spills too large for the normally equipped laboratory worker and too small to require the response by the local fire department or contractors. The Spill Team is a volunteer organization of men and women who have an interest and/or expertise in emergency response, chemistry or laboratory management. Over the years, the Spill Team has successfully filled the niche between the laboratory worker, local fire and rescue units and costly hazardous materials clean-up contractors. The Spill Team goal is to lend continuity, efficiency, effectiveness and economy to response efforts in both large and small scale incidents.

U.S. GEOLOGICAL SURVEY HAZARDOUS CHEMICAL SPILL TEAM

CIRCE', Ronald, U.S. Geological Survey, 914 National Center, Reston Virginia 22092, Wayne Martin, U.S. Geological Survey, 953 National Center, Reston Virginia 22092, and Randall Orndorff, U.S. Geological Survey, 902 National Center, Reston Virginia 22092,

The development of an in-house hazardous chemical spill response team as part of an organization's Occupant Emergency Plan is becoming a standard throughout industry and Government. The effectiveness of such a team depends primarily on the quality, quantity and appropriateness of training that response personnel receive. The most common type of chemical emergency occurring within the U. S. Geological Survey is of a magnitude greater than the average laboratory worker can control yet of a size that a well trained and equipped in-house Hazardous Chemical Spill Team can readily manage.

The U.S. Geological Survey National Center Hazardous Chemical Spill Team was formed in 1982 as a result of an accident in a chemical stock room. This incident exposed the weakness of not having an organized plan for responding and managing chemical spills at the National Center. With over 3500 different chemicals and 167 chemical laboratories, the Spill Team was formed to handle spills too large for the normally equipped laboratory worker and too small to require the response by the local fire department or contractors. The Spill Team is a volunteer organization of men and women who have an interest and/or expertise in emergency response, chemistry or laboratory management. Over the years, the Spill Team has successfully filled the niche between the laboratory worker, local fire and rescue units and costly hazardous materials clean-up contractors. The Spill Team goal is to lend continuity, efficiency, effectiveness and economy to response efforts in both large and small scale incidents.

The Chemical Hygiene Plan as a Tool for Hazardous Waste Management

KRAMER, Gary W., U.S. Geological Survey, 246 National Center, Reston, VA
22092

Hazardous waste managers of laboratory facilities are faced with increasing waste disposal costs as well as stricter waste management requirements. Establishing effective Chemical Hygiene Plans for each laboratory can eliminate hazardous material spills and resultant cleanup and waste disposal and will identify and help to reduce hazardous waste streams. This topic demonstrates how Chemical Hygiene Plans can be an effective tool in an overall hazardous waste management program.

The topic focuses on the following:

- Components of the Chemical Hygiene Plan
- Describes use of job hazard analyses to pinpoint sources of spills
- Use of the plan to establish hazardous waste disposal procedures
- Identifying potential spill sources in unattended or overnight operations
- Emergency preparedness in the event of a spill

ATTENDEES

Achuff, Jonathan M.
Bureau of Mines
P.O. Box 25086
Denver Fed. Center, Bldg. 20
Denver, CO 80225
Phone: 303-236-3400
FAX:

Akins, Ronald G.
Bureau of Reclamation
P.O. Box 159
Red Bluff, CA 96080
Phone: 916-529-3890
FAX: 916-529-3895

Allerton, David K.
U.S. Geological Survey
P.O. Box 25046
Denver Fed. Center, MS907
Denver, CO 80225
Phone: 303-236-5635
FAX: 303-236-5603

Altringer, Paulette
Bureau of Mines
729 Arapeen Dr.
Salt Lake City, UT 84108
Phone: 801-584-4152
FAX: 801-584-4134

Anttila, Pete
U.S. Geological Survey
345 Middlefield Rd
MS 470
Menlo Park, CA 94025
Phone:
FAX:

Artz, Ned
Bureau of Reclamation
P.O. Box 11568
Salt Lake City, UT 84117
Phone: 801-524-5442
FAX: 801-524-5499

Adams, Briane
U.S. Geological Survey
3850 Holcomb Bridge Rd.
Suite 160
Norcross, GA 30092
Phone: 404-409-7700
FAX: 404-409-7725

Allan, William C.
Office of Environ. Affairs
Bldg. 56, Rm. 1003
P.O. Box 25007 (D-108)
Denver, CO 80225-0007
Phone: 303-236-6900
FAX: 303-236-4093

Allgaier, Frederick K.
Bureau of Mines
P.O. Box 25086
Denver Fed. Center, Bldg. 20
Denver, CO 80225
Phone: 303-236-0769
FAX: 303-236-0828

Angel, Tammy
Fish & Wildlife Service
P.O. Box 25207
Denver, CO 80225-0207
Phone:
FAX:

Archuleta, Andrew
Fish & Wildlife Service
730 Simms St.
Suite 290
Golden, CO 80401
Phone:
FAX:

Atkins, Lynn
Bureau of Mines
Spokane Research Center
East 31 Montgomery Ave.
Spokane, WA 99207
Phone: 509-484-1610
FAX: -

Averill, Marilyn
Solicitor
P.O. Box 25007
Denver, CO 80225
Phone: 303-231-5353
FAX: 303-231-5363

Barkow, Lee
Bureau of Land Management
P.O. Box 25047
Denver Fed. Center
Denver, CO 80225-0047
Phone: 303-236-8857
FAX: 303-236-3508

Beach, Richard A.
Bureau of Mines
P.O. Box 25086
Denver Fed. Center, Bldg. 20
Denver, CO 80225
Phone: 303-236-0423
FAX: 303-236-0238

Berg, Steven
U.S. Geological Survey
3916 Sunset Ridge Rd.
Raleigh, NC 27607
Phone:
FAX:

Bianchi, Robert H.
Bureau of Reclamation
P.O. Box 25007
Bldg. 67
Denver, CO 80225-0007
Phone: 303-236-6913
FAX: 303-236-4711

Birks, Brenda
Bureau of Reclamation
D-7813
P.O. Box 25007
Denver, CO 80225
Phone: 303-236-3771
FAX: 303-236-8630

Balderrama, Robert
Bureau of Mines
1605 Evans Ave.
Reno, NV 89512-2295
Phone: 702-334-6644
FAX: 702-334-6603

Barrell, Steve
Bureau of Land Management
P.O. Box 25047
Denver Fed. Center
Denver, CO 80225-0047
Phone: 303-236-8857
FAX: 303-236-3508

Benevides, Micheal
Office of Surface Mining
1020 15th St.
Denver, CO 80202
Phone: 303-844-4072
FAX: 303-844-2538

Betterton, William
U.S. Geological Survey
Box 25046, MS 972
Denver Fed. Center
Denver, CO 80225
Phone: 303-236-8290
FAX: 303-236-7738

Bierbach, Peter R.
Bureau of Land Management
Box 36800
Billings, MT 59107
Phone:
FAX:

Blakeslee, Mark
Bureau of Land Management
New Mexico State Office
P.O. Box 27115
Santa Fe, NM 87502-0115
Phone: 505-438-7424
FAX: 505-438-7426

Blanchard, Mary Josie
Office of Environ. Affairs
1849 C St., NW
MIB-2340
Washington, DC 20240
Phone: 202-208-7877
FAX: 202-208-6970

Booth, Bibi
Bureau of Land Management
Eastern States
7450 Boston Blvd.
Springfield, VA 22153
Phone: 703-440-1726
FAX: 703-440-1599

Bowles, Gerry
Bureau of Reclamation
P.O. Box 25007
Denver Fed. Center
Denver, CO 80225
Phone: 303-236-8646
FAX: 303-236-0017

Boynton, June
Bureau of Indian Affairs
911 NE 11th Ave.
Portland, OR 97232-4169
Phone: 503-231-6749
FAX: 503-231-2275

Brightman, Hank J.
National Park Service
North Atlantic Regional Office
15 State Street
Boston, MA 02109
Phone: 617-223-5066
FAX: 617-223-5165

Brown, James G.
U.S. Geological Survey
375 S. Euclid Ave.
Tucson, AZ 85719-6644
Phone: 602-670-6023
FAX: 602-670-5592

Bolstad, Doug
Bureau of Mines
E. 315 Montgomery Ave.
Spokane, WA 99207
Phone:
FAX:

Bossong, Kip
U.S. Geological Survey
7th & C Sts.
Commerce City, CO 80022
Phone:
FAX:

Bowser, Steven R.
Bureau of Reclamation
P.O. Box 11568
Salt Lake City, UT 84147
Phone:
FAX:

Braidech, Tom
Bureau of Reclamation
(D-5820)
Denver Fed. Center, Bldg. 67
Denver, CO 80225
Phone: 303-236-5245
FAX: 303-236-0891

Broshears, Robert E.
U.S. Geological Survey
P.O. Box 25046
Denver Fed. Center, MS-415
Denver, CO 80225
Phone:
FAX:

Brownfield, Michael
U.S. Geological Survey
Box 25046, MS 972
Denver Fed. Center
Denver, CO 80225
Phone: 303-236-7767
FAX: 303-236-7778

Buelna, Antonio M.
Bureau of Reclamation
2666 N. Grove Industrial Dr.
#106
Fresno, CA 93727-1551
Phone: 209-487-5117
FAX: 209-487-5397

Byrd, Terry L.
Bureau of Mines
801 S. Fillmore
Suite 500
Amarillo, TX 79101-3545
Phone: 806-376-2677
FAX: 806-376-2633

Cameron, Charles H.
Bureau of Indian Affairs
P.O. Box 130
Ft. DuChesne, UT 84026
Phone: 801-722-2406
FAX: 801-722-2406

Case, Lee
U.S. Geological Survey
Rm 1016, Admin Bldg
1745 W. 1700 S.
Salt Lake City, UT 84060
Phone: 801-975-3350
FAX: 801-975-3424

Cender, Cheryl
Bureau of Land Management
5050 N. 19th Ave., #300
Phoenix, AZ 85015
Phone: 602-336-6605
FAX: 602-336-6555

Chamberlain, Peter
Bureau of Mines
5629 Minnehaha Ave., S.
Minneapolis, MN 55417
Phone: 612-725-4722
FAX: 612-725-4526

Buller, Randy
Bureau of Indian Affairs
Natural Resources
P.O. Box 1667
Albuquerque, NM 87103
Phone: 505-766-3028
FAX: 505-766-3023

Calderon, Lupe
Bureau of Mines
1605 Evans Ave.
Reno, NV 89523
Phone: 702-334-6694
FAX: 702-334-6603

Carter, Olice C.
Bureau of Mines
P.O. Box L
University of AL Campus
Tuscaloosa, AL 35486-9977
Phone: 205-759-9435
FAX: 205-759-9440

Cathcart, James D.
U.S. Geological Survey
Box 25046, MS 972
Denver Fed. Center
Denver, CO 80225
Phone: 303-236-7780
FAX: 303-236-3200

Chaffin, John
Solicitor's Office
P.O. Box 31394
Billings, MT 59107-1394
Phone: 406-657-6331
FAX: 406-657-6682

Church, Ronald
Bureau of Mines
1104 Lakeridge Dr.
Birmingham, AL 35244
Phone: 205-759-9446
FAX: 205-759-9440

Clark, Kris
Solicitor's Office
1849 C St. NW
MIB-6312
Washington, DC 20240
Phone:
FAX:

Clifton, Ronald W.
Bureau of Reclamation
23636 N. 7th St.
P.O. Box 9980
Phoenix, AZ 85068
Phone: 602-870-2478
FAX: 602-870-2815

Coleman, James H.
Fish & Wildlife Service
1011 E. Tudor Rd.
Anchorage, AK 99503
Phone: 907-786-3346
FAX: 907-786-3636

Condon, Joseph
Bureau of Mines
P.O. Box 25086
Denver Fed. Center, Bldg. 20
Denver, CO 80225
Phone: 303-236-9065
FAX: 303-236-0828

Cook, Vicki
Bureau of Reclamation
P.O. Box 25007
Code D-7813
Denver, CO 80225
Phone: 303-236-8045
FAX: 303-236-8630

Craynon, John
Office of Environ. Affairs
1849 C St. NW
2340-MIB
Washington, DC, 20240
Phone: 202-208-7555
FAX: 202-208-6970

Claus, Bonnie
U.S. Geological Survey
MS 934, Denver Fed. Center
P.O. Box 25046
Denver, CO 80225
Phone: 303-236-5717
FAX: 303-236-8822

Clingan, Richard S.
MMS
222 W. Carmen Lane
Suite 201
Santa Maria, CA 93454
Phone: 805-922-7958
FAX: 805-925-8546

Coleman, Leo E.
Bureau of Land Management
P.O. Box 2420
815 Connie St.
Mills, WY 82644
Phone: 307-261-7504
FAX: 307-267-7528

Cook, James E.
Bureau of Mines
810 7th St., NW
MS 6200
Washington, DC, 20241
Phone: 202-401-9293
FAX: 202-501-9957

Cornell, William L.
Bureau of Mines
P.O. Box 280
Rolla, MO 65401
Phone: 314-364-3169
FAX: 314-364-7350

Crock, James G.
U.S. Geological Survey
Box 25046, MS 973
Denver Fed. Center
Denver, CO 80225
Phone: 303-236-2452
FAX: 303-236-3200

Cruz, Rayleen
Bureau of Reclamation
Denver Office, POB 25007
Bldg. 67, Rm. 128
Denver, CO 80225
Phone:
FAX:

Darnell, Joan
National Park Service
Alaska Regional Office
2525 Gambell Street, Rm. 107
Anchorage, AK 99503
Phone: 907-257-2648
FAX: 907-257-2517

Davis, Bruce
Bureau of Land Management
1235 La Plata Hwy.
Farmington, NM 87401
Phone: 505-599-8958
FAX: 505-599-8998

Deason, Jonathan P.
Office of Environ. Affairs
1849 C St., NW
Washington, DC 20240
Phone: 202-208-3891
FAX: 202-208-6970

Deverel, Steven J.
U.S. Geological Survey
2800 Cottage Way
W-2233
Sacramento, CA 95825
Phone: 916-978-4633
FAX: 916-978-5558

Dix, Russell B.
Bureau of Mines
1605 Evans Ave.
Reno, NV 89512-2295
Phone: 702-334-6600
FAX: 702-334-6603

Cunningham, Curtis G.
Bureau of Mines
729 Arapeen Dr.
Salt Lake City, UT 84108
Phone: 801-584-4158
FAX: 801-584-4134

Davis, Barry
National Park Service
P.O. Box 25287
Denver, CO 80225
Phone:
FAX:

Deal, Harriet M.
Solicitor's Office
RB Russell Fed. Bldg.
75 Spring St., #304
Atlanta, GA 30303
Phone: 404-331-3379
FAX: 404-730-2682

Detra, David
U.S. Geological Survey
Box 25046, MS 973
Denver Fed. Center
Denver, CO 80225
Phone:
FAX:

Devine, James F.
U.S. Geological Survey
106 National Center
Reston, VA 22092
Phone: 703-648-4423
FAX: 703-648-4466

Dockery, Bill
MMS
381 Eldon St.
MS 4700
Herndon, VA 22070
Phone: 703-787-1548
FAX: 703-787-1575

Doe, Phillip
Bureau of Reclamation
P.O. Box 25007
D-5620
Denver, CO 80225
Phone: 303-236-1061
FAX: 303-236-3573

Dollar, Melissa S.
Bureau of Reclamation
P.O. Box 25007
Denver Fed. Center, Bldg. 67, Rm. 1400
Denver, CO 80225-0007
Phone: 303-236-9009
FAX:

Dudley, Ryan L
Bureau of Land Management
5902 Mt. Eagle Dr. #1015
Alexandria, VA 22303
Phone: 202-653-7574
FAX:

Dune, Michael
National Park Service
RMR-PP
P.O. Box 25287
Denver, CO 80225
Phone:
FAX:

Eckhardt, Doris
Bureau of Reclamation
Rt. 1, Box 35
Byron, GA 94514-9614
Phone: 209-836-6281
FAX: 209-836-6264

Eggers, Ron
Bureau of Indian Affairs
911 NE 11th Ave.
Portland, OR 97232-4169
Phone:
FAX:

Doebbler, Krista
Bureau of Reclamation
2800 Cottage Way
Sacramento, CA 95825
Phone: 916-978-5046
FAX: 916-978-5284

Dolzani, Roger L.
Bureau of Mines
P.O. Box 25086
Bldg. 20, Denver Fed. Center
Denver, CO 80225
Phone: 303-236-0423
FAX: --

Duke, Chris
Bureau of Reclamation
P.O. Box 25007
Denver Fed. Center, Bldg. 67
Denver, CO 80225-0007
Phone: 303-236-4059
FAX: 303-236-3929

Eades, Natalie
Solicitor's Office
1849 C St., NW
6312-MIB
Washington, DC 20240
Phone: 202-208-5360
FAX: 202-219-1972

Eddington, Jeff
Bureau of Reclamation
P.O. Box D
Yuma, AZ 85366
Phone: 602-343-8448
FAX: 602-343-8320

Ellis, John C.
Bureau of Reclamation
P.O. Box 25007
Denver Fed. Center, Bldg. 67, Rm. 1400
Denver, CO 80225-0007
Phone:
FAX:

Engdahl, Lynn
Bureau of Land Management
5050 N. 19th Ave., #300
Phoenix, AZ 85015
Phone: 602-336-6500
FAX: 602-336-6555

Fair, Tom
National Park Service
P.O. Box 25287
Denver, CO 80225
Phone: 303-969-2031
FAX: 303-987-6658

Fields, John
Bureau of Reclamation
MP-705, 2800 Cottage Way
Sacramento, CA 95831
Phone: 916-798-5581
FAX: 916-978-5284

Fisk, Gary
Bureau of Reclamation

Denver, CO
Phone:
FAX:

Fitzpatrick, Bill
U.S. Geological Survey
345 Middlefied Rd.
MS 225
Menlo Park, CA 94025
Phone: 415-329-4164
FAX: 415-329-5095

Fore, Dr. Paul
Fish & Wildlife Service
P.O. Box 1306
Albuquerque, NM 87103
Phone: 505-766-2914
FAX: 505-766-8063

Erdman, James
U.S. Geological Survey
Box 25046, MS 973
Denver Fed. Center
Denver, CO 80225
Phone:
FAX:

Faithful, Robert W.
Bureau of Land Management
1849 C St.
MS 5617
Washington, DC 20240
Phone: 202-208-3897
FAX: 202-208-5561

Fisher, Richard B.
National Park Service
1709 Jackson St.
Omaha, NE 68102
Phone: 402-221-3423
FAX: 402-221-3463

Fitterman, David
U.S. Geological Survey
Box 25046
Denver Fed. Center, MS-964
Denver, CO 80225
Phone:
FAX:

Ford, Karl
Bureau of Land Management
P.O. Box 25047
Denver Fed. Center
Denver, CO 80025-0047
Phone: 303-236-8857
FAX: 303-236-3508

Forester, Richard T.
Bureau of Land Management
2800 Cottage Way
Sacramento, CA 95825
Phone: 916-978-4725
FAX: 916-978-4715

Freeman, Jon
Bureau of Reclamation
P.O. Box 640
Durango, CO 81302
Phone: 303-385-6562
FAX: 303-385-6539

Fritz, Dan
Bureau of Reclamation
P.O. Box 640
Durango, CO 81302
Phone: 303-385-6567
FAX: 303-385-6539

Fuller, Timothy D.
Bureau of Land Management
Shoshone District
P.O. Box 2-B
Shoshone, ID 83352
Phone: 208-886-7273
FAX: 208-886-7317

Furqueron, Chris
National Park Service
Suite 1022
75 Spring St., SW
Atlanta, GA 30064
Phone:
FAX:

Gallamore, Allen
National Park Service
Denver Service Center
P.O. Box 25287
Denver, CO 80225
Phone: 303-969-6966x252
FAX: 303-969-6966

Gates, Paul D.
Office of Environ. Affairs
1689 C Street
Room 119
Anchorage, AK 99501-5126
Phone: 907-271-5011
FAX: 907-271-4102

Frieders, Twila
Bureau of Mines
810 7th St., NW
Washington, DC 20241-0002
Phone:
FAX:

Fuerst, Richard
Bureau of Reclamation
P.O. Box 25007
Denver Fed. Center, Bldg. 67
Denver, CO 80225
Phone:
FAX:

Funke, Michael G.
National Park Service
Denver Service Center
12795 W. Alameda Pkwy.
Denver, CO 80225
Phone:
FAX:

Galetovic, Joe
Office of Surface Mining
1020 15th ST
2nd Floor, Brooks Towers
Denver, CO 80202
Phone:
FAX:

Gary, Patrick
Bureau of Reclamation
P.O. Box 9980
Phoenix, AZ 85068
Phone:
FAX:

Gebhardt, Karl
Bureau of Land Management
Idaho State Office
3380 Americana Terr.
Boise, ID 83706
Phone: 208-384-3080
FAX: 208-384-3083

Gemperline, Mark C.
Bureau of Reclamation
Bldg. 56, Denver Fed. Center
P.O. Box 25007
Denver, CO 80225
Phone: 303-236-4319
FAX: 303-236-4679

Ging, Tom
U.S. Geological Survey
Box 25046
Denver Fed. Center-MS 973
Denver, CO 80225
Phone: 303-236-5733
FAX: 303-236-3200

Goddard, Kimball E.
U.S. Geological Survey
375 South Euclid Ave.
Tucson, AZ 85719
Phone: 602-670-6135
FAX: 602-670-5592

Gordon, Larry
Bureau of Reclamation
P.O. Box 11568
Salt Lake City, UT 84147
Phone: 801-524-5544
FAX: 801-524-5499

Griffith, Marty
Bureau of Land Management
Wyoming State Office
2515 Warren Ave.
Cheyenne, WY 82001
Phone: 307-775-6093
FAX: 307-775-6082

Guerrero, Daniel
Fish & Wildlife Service
RMA Bldg. 111
Commerce City, CO 80022-2180
Phone:
FAX:

Gernerd, Kurt A.
Office of Construction Mgmt.
MS-2417 MIB
1849 C St., NW
Washington, DC, 20240
Phone: 202-208-5399
FAX: 202-219-2390

Gober, Donald R.
Fish & Wildlife Service
Bldg. 111
Rocky Mtn. Arsenal
Commerce City, CO 80022
Phone: 303-289-0232
FAX: 303-289-0579

Gordon, Bill
DOI-POB
1849 C St., NW
4455 MIB
Washington, DC 20245
Phone:
FAX:

Griess, Jane
Fish & Wildlife Service
Bldg. 111
Rocky Mtn. Arsenal
Commerce City, CO 80022
Phone: 303-289-0232
FAX: 303-289-0579

Griffith, Roger
Bureau of Land Management
18th & C Sts., NW
Washington, DC, 20240
Phone:
FAX:

Guy, Gina
Solicitor
P.O. Box 25007
(D-105)
Denver, CO 80225
Phone: 303-231-5353
FAX: 303-231-5363

Haegele, Max
Bureau of Reclamation
P.O. Box 25007
D-5620
Denver, CO 80225
Phone: 303-236-1061X249
FAX: 303-236-3573

Heirendt, Barbara
Bureau of Mines
P.O. Box 18070
Cochrans Mill Road
Pittsburgh, PA 15236
Phone: 412-892-6861
FAX: 412-892-4286

Heuslein, Amy L.
Bureau of Indian Affairs
One North First St.
P.O. Box 10
Phoenix, AZ 85001
Phone:
FAX:

Hext, Ken
Bureau of Land Management
6881 Abbott Loop Rd.
Anchorage, AK 99507
Phone: 907-267-1470
FAX: 907-267-1250

Hollop, Edward E.
Bureau of Mines
P.O. Box 25086
Building 20, Denver Fed. Center
Denver, CO 80225
Phone: 303-236-0697
FAX: 303-236-0828

Hren, Janet
U.S. Geological Survey
345 Middlefield Rd
MS 470
Menlo Park, CA 94025
Phone: 415-329-4447
FAX: 415-329-4463

Hart, Ward
Bureau of Land Management
P.O. Box 25047
Denver Fed. Center
Denver, CO 80225-0047
Phone: 303-236-8857
FAX: 303-236-3508

Henne, Donald R.
Office of Environ. Affairs
200 Chestnut St.
Custom House, Rm. 217
Philadephia, PA 19106
Phone: 215-597-5378
FAX: 215-597-9845

Hewitt, Julia
National Park Service
1100 Ohio Drive, SW
Washington, DC, 20242
Phone: 202-523-5675
FAX: 202-523-0460

Hogue, Marilyn
National Park Service
12795 W. Alameda Pkwy.
Lakewood, CO 80228
Phone:
FAX:

Hotchkiss, William R.
U.S. Geological Survey
Box 25046, MS 406
Denver Fed. Center
Lakewood, CO 80225-0046
Phone: 303-236-5928
FAX: 303-236-5959

Hudson, Marilyn
Bureau of Reclamation
P.O. Box D
Yuma, AZ 85366
Phone: 602-343-8227
FAX: 602-343-8320

Huff, Sheila M.
Office of Environ. Affairs
230 South Dearborn St.
Room 3422
Chicago, IL 60604
Phone: 312-353-6612
FAX: 312-353-1051

Huntt, Caryn
Bureau of Reclamation
P.O. Box 640
Carson City, NV 89701
Phone: 702-882-3436
FAX: 702-882-7592

Jac, Beverly C.
Office of Environ. Affairs
1849 C St., NW
2340-MIB
Washington, DC 20240
Phone:
FAX:

Jakabosky, Jake
Bureau of Land Management
E. 4217 Main Ave.
Spokane, WA 99202
Phone: 509-353-2570
FAX: -

Jennings, David
Bureau of Reclamation
P.O. Box 61470
Boulder City, NV 89006-1470
Phone: 702-293-8144
FAX: 702-293-8146

Johnson, Betty S.
Bureau of Reclamation
18th & E Sts., NW
7550-MIB
Washington, DC 20240
Phone: 202-208-4391
FAX: 202-208-3378

Hunt, Steven
National Park Service
NP5-OE
P.O. Box 25287
Denver, CO 80225
Phone: 303-969-2089
FAX: 303-969-2034

Hyman, David M.
Bureau of Mines
P.O. Box 18070
Pittsburgh, PA 15236
Phone: 412-892-6572
FAX: 412-892-4067

Jackson, Rhio
Bureau of Land Management
P.O. Box 25047
Denver Fed. Center
Denver, CO 80225-0047
Phone: 303-236-8857
FAX: 303-236-3508

Jenkins, Gerri
Bureau of Land Management
1849 C St.
MS 5617
Washington, DC 20240
Phone: 202-208-6467
FAX: 202-208-5561

Jewell, Dan
Bureau of Reclamation
301 N. 27th St.
Suite 200
Billings, MT 59101
Phone: 406-657-6870
FAX: 406-657-6474

Johnson, Guy A.
Bureau of Mines
P.O.Box 25086
Denver, CO 80225
Phone: 303-236-0747
FAX: 303-236-0888

Johnson, Toni M
U.S. Geological Survey
407 National Center
Reston, VA 22092
Phone: 703-648-6810
FAX: 703-648-5295

Jong, Harry T.
Bureau of Reclamation
P.O. Box 25007
Denver, CO 80235-0007
Phone: 303-236-9096
FAX: 303-236-9078

Keeler, Kevin
National Park Service
2525 Gambell St.
Anchorage, AK 99503
Phone: 907-257-2645
FAX: 907-257-2517

Khattat, Frank H.
Bureau of Indian Affairs
MIB-4559
Washington, DC, 20240
Phone: 202-208-3959
FAX: 202-208-5493

Kinney, James L.
Bureau of Reclamation
P.O. Box 25007
Denver Fed. Center, Bldg. 67, Rm. 1400
Denver, CO 80225-0007
Phone: 303-236-0327
FAX: --

Kirk, Keith
Office of Surface Mining
1020 15th St
TAD-TIPS
Denver, CO 80202
Phone: 303-844-4072
FAX: 303-844-2538

Jones, Perry
Bureau of Mines
5629 Minnehaha Ave., S
Minneapolis, MN 55417
Phone: 612-725-4680
FAX: 612-725-4526

Kaas, L. Michael
Bureau of Mines
810 7th St., NW
Washington, DC 20241-0002
Phone:
FAX:

Kelly, Linda J.
National Park Service
12795 W. Alameda Pkwy.
P.O. Box 25287
Denver, CO 80225-0287
Phone: 303-969-6956 X235
FAX: 303-969-6966

Killoran, Linda
Bureau of Mines
P.O. Box 25086
Denver Fed. Center, Bldg. 20
Denver, CO 80225
Phone: 303-236-0792
FAX: 303-236-0828

Kinney, Jr., Leo A.
Bureau of Reclamation
P.O. Box 25007
Denver Fed. Center, Bldg. 67
Denver, CO 80225
Phone: 303-236-3953
FAX: 303-236-3929

Klein, John M.
U.S. Geological Survey
2800 Cottage Way
Rm. 2234
Sacramento, CA 95825
Phone: 916-978-4633
FAX: 916-978-5558

Kline, Duaine J.
Bureau of Reclamation
6600 Washburn Way
Klamath Falls, OR 97603
Phone: 503-883-6935
FAX: 503-884-9053

Knutsen, Galen C.
Bureau of Mines
P.O. Box 25086
Bldg. 20, Denver Fed. Center
Denver, CO 80225
Phone: 303-236-0421
FAX: 303-236-0238

Kramer, Gary
U.S. Geological Survey
246 National Center
Reston, VA 22092
Phone: 703-648-7556
FAX: 703-648-7414

Kreger, David
National Park Service
Denver Service Center
P.O. Box 25287
Denver, CO 80225
Phone: 303-969-6956
FAX: 303-969-6966

Kummler, Ralph
Wayne State University
WSU, College of Engineering
Detroit, MI 48202
Phone: 313-577-3800
FAX: 313-577-3810

Kunzer, Elizabeth
Bureau of Reclamation
Bldg. 56, Denver Fed. Center
P.O. Box 25007
Denver, CO 80225
Phone: 303-236-4323
FAX: --

Kline, Larry
Office of Surface Mining
1020 15th St.
TAD-TIPS
Denver, CO 80202
Phone:
FAX:

Koselak, Janine
Bureau of Land Management
P.O. Box 25047
Denver Fed. Center
Denver, CO 80225-0047
Phone: 303-236-8857
FAX: 303-236-3508

Krause, John F.
Bureau of Reclamation
P.O. Box 9980
Phoenix, AZ 85068
Phone: 602-870-6714
FAX: 602-870-6788

Krueger, Rick
Fish & Wildlife Service
529 25 1/2 Rd
Suite B113
Grand Junction, CO 81505
Phone:
FAX:

Kunicki, Raymond G.
Bureau of Mines
810 7th, NW
MLS 2192
Washington, DC, 20241
Phone: 202-501-9805
FAX: --

Kurtz, Connie
Office of Environ. Affairs
1849 C St.
2340-MIB
Washington, DC 20240
Phone:
FAX:

Lange, Debra
Bureau of Reclamation
P.O. Box 25007, Bldg. 67
Rm. 128, Denver Fed. Center
Denver, CO 80225
Phone: 303-236-6793
FAX: 303-236-0544

Langer, Greg
Fish & Wildlife Service
RMA Bldg. 111
Commerce City, CO 80022-2180
Phone: 303-289-0232
FAX: 303-289-0579

Lee, James
Office of Environ. Affairs
306 Federal Bldg.
75 Spring St., SW
Atlanta, GA 30303
Phone: 404-331-4524
FAX: 404-331-1736

Lesley, Cecil H.
Bureau of Reclamation
7794 Folsom Dam Rd.
Folsom, CA 95630
Phone:
FAX:

Lewis, Brent
Bureau of Land Management
P.O. Box 25047
Denver Fed. Center
Denver, CO 80225-0047
Phone: 303-236-8857
FAX: 303-236-3508

Lins, Sue
Bureau of Mines
P.O. Box 10807
Pittsburg, PA 15236
Phone:
FAX:

Langelier, Lisa
Fish & Wildlife Service
RMA Bldg. 111
Commerce City, CO 80022-2180
Phone: 303-289-0232
FAX: 303-289-0579

Lasson, Richard
Bureau of Reclamation
P.O. Box 11568
Salt Lake City, UT 84147
Phone: 801-524-5520
FAX: 801-524-5499

Leipnik, Mark
Bureau of Reclamation
MS LC 277
400 Railroad Ave.
Boulder City, NV 89005
Phone: 702-293-8148
FAX: 702-293-8146

Levens, Russell
Bureau of Mines
Spokane Research Center
East 315 Montgomery Ave.
Spokane, WA 99207
Phone: 509-484-1610
FAX:

Lewis, David L.
Bureau of Land Management
3380 Americana Terrace
Boise, ID 83706
Phone:
FAX:

Long, Debbie
Fish & Wildlife Service
RMA Bldg. 111
Commerce City, CO 80022-2180
Phone: 303-289-0232
FAX: --

Longwell, Barry D.
Bureau of Reclamation
P.O. Box 5189
VandenBerg AFB, CA 93437
Phone: 805-734-2219
FAX: 805-734-1589

Loomis, Dean
Bureau of Reclamation
P.O. Box 36900
Mail Code GP-152
Billings, MT 59107-6900
Phone: 406-657-6605
FAX: 406-657-6474

Lovley, Derek
U.S. Geological Survey
430 National Center
Reston, VA 22092
Phone:
FAX:

Lowe, Ted
Bureau of Mines
E. 360 Third Ave.
Spokane, WA 99202
Phone:
FAX:

Lucas, Dee
U.S. Geological Survey
Box 25046, MS 205
Denver Fed. Center
Denver, CO 80225
Phone: 303-236-5900
FAX: -

Lucius, Jeff
U.S. Geological Survey
Box 25046
Denver Fed. Center, MS964
Denver, CO 80225-0046
Phone: 303-326-1413
FAX: 303-236-1425

Lund, Scott
Bureau of Reclamation
1150 N. Curtis
Boise, ID 83706-1234
Phone: 208-378-5037
FAX: 208-378-5066

Mahooty, Clifford
Bureau of Indian Affairs
P.O. Box 2243
Albuquerque, NM 87103
Phone: 505-766-2456
FAX: 505-766-3493

Mallard, Gail
U.S. Geological Survey
412 National Center
Reston, VA 22092
Phone: 703-648-6872
FAX: 703-648-5295

Martin, Wayne
U.S. Geological Survey
953 National Center
Reston, VA 22092
Phone: 703-648-5289
FAX: --

Martinez, Josue
Fish & Wildlife Service
P.O. Box 1306
500 Gold Ave., SW
Albuquerque, NM 87103
Phone:
FAX:

McCaig, Robert E.
Bureau of Reclamation
P.O. Box 25007
D-5930
Denver, CO 80225
Phone: 303-236-6351
FAX: --

McClendon, Monte L.
Bureau of Reclamation
1150 N. Curtis Rd.
Boise, ID 83706-1234
Phone: 208-378-5036
FAX: 208-378-5066

McKeown, Mark H.
Bureau of Reclamation
P.O. Box 25007
Bldg. 67
Denver, CO 80225-0007
Phone: 303-236-0661
FAX: 303-236-4711

Meredith, James
Office of Safety & Occu. Health
P.O. Box 25007
Denver Fed. Center
Denver, CO 80225
Phone: 303-231-5208
FAX: 303-231-5222

Meyer, Paul
Bureau of Land Management
5050 N. 19th Ave., #300
Phoenix, AZ 85015
Phone: 602-336-6544
FAX: 602-336-6555

Middelburg, Robert .
U.S. Geological Survey
Box 25046, MS 415
Denver Fed. Center
Lakewood, CO 80225
Phone:
FAX:

Montgomery, Jerry
Bureau of Mines
729 Arapeen Drive
Salt Lake City, UT 84120
Phone: 801-584-4117
FAX: 801-584-4119

McCracken, Michael J.
Bureau of Land Management
1701 East E St.
Casper, WY 82601
Phone: 307-261-7682
FAX: 307-234-1525

McNeal, James M.
U.S. Geological Survey
910 National Center
Reston, VA 22092
Phone: 703-648-6650
FAX: 703-648-6683

Meunier, Thomas E.
Bureau of Reclamation
P.O. Box 51338
Provo, UT 84605-1338
Phone: 801-379-1205
FAX: 801-379-1159

Michel, Roger P.
Bureau of Reclamation
P.O. Box 36900
Mail Code GP159
Billings, MT 59107
Phone: 406-657-6108
FAX: 406-657-6474

Miller, Margaret
Bureau of Reclamation
D-7813
P.O. Box 25007
Denver, CO 80225
Phone: 303-236-8049
FAX: 303-236-8630

Moore, Elaine
Fish & Wildlife Service
RR 3 - Box 328
Marion, IL 62959
Phone:
FAX:

Morin, Kenneth D.
Bureau of Land Management
P.O. Box 25047
Denver Fed. Center, Bldg. 50
Denver, CO 80225-0047
Phone: 303-236-6418
FAX: 303-236-8867

Morris, Thomas
Bureau of Land Management
P.O. Box 25047
Denver Fed. Center
Denver, CO 80225-0047
Phone: 303-236-8857
FAX: 303-236-3508

Murphy, John N.
Bureau of Mines
P.O. Box 18070
Pittsburgh, PA 15236
Phone: 412-892-6601
FAX: 412-892-6614

Naser, Kenneth D.
Office of Environ. Affairs
1849 C St., NW
2340-MIB
Washington, DC 20240
Phone: 202-208-3901
FAX:

Nelson, Herb
Bureau of Indian Affairs
331 Second Ave., SO.
Minneapolis, MN 55401-2241
Phone:
FAX:

Niven, Neal T.
Bureau of Reclamation
2666 N. Grove Industrial Dr.
#106
Fresno, CA 93727-1551
Phone: 209-487-5339
FAX: 209-487-5397

Morris, Barbara
Bureau of Land Management
1849 C St., NW
MS 407 LS
Washington, DC, 20240
Phone: 202-653-7574
FAX: 202-653-9872

Mulligan, Shawn P.
National Park Service
12795 W. Alameda Pkwy.
Lakewood, CO 80228
Phone: 303-969-2065
FAX: 303-969-2034

Murphy, William J.
Bureau of Land Management
Oregon State Office
P.O. Box 2965
Portland, OR 97208-2965
Phone: 503-280-7064
FAX: 503-280-7021

Nash, Boyd
Bureau of Mines
1450 Queen Ave. SW
Albany, OR 97321
Phone: 503-967-5883
FAX: 503-967-5905

Nieves, Ramon
Bureau of Reclamation
Route 1, Box 35
Byron, CA 94514
Phone: 209-836-6236
FAX: 209-836-6264

Nordstrom, D. Kirk
U.S. Geological Survey
3215 Marine St.
Room E109
Boulder, CO 80303-1066
Phone:
FAX:

Norton, Shawn
National Park Service
4708 Sheridan St.
Riverdale, MD 20737
Phone: 202-343-7040
FAX: 202-523-5186

O'Hare, Steven
Bureau of Mines
1450 Queen Ave., SW
Albany, OR 97321
Phone: 503-967-5911
FAX:

Olheoft, Gary R.
U.S. Geological Survey
Denver Fed. Center-MS 964
Box 25046
Denver, CO 80225
Phone: 303-236-1302
FAX: --

Ortiz, Jim
Office of Environ. Affairs
1849 C St., NW
2340-MIB
Washington, DC 20240
Phone: 202-208-7553
FAX: 202-208-6970

Osmundson, Barb
Fish & Wildlife Service
529 25 1/2 Rd.
Suite B113
Grand Junction, CO 81505
Phone:
FAX:

Padovani, Elaine
Office of Environ. Affairs
905 National Center
Reston, VA 22092
Phone: 703-648-6638
FAX: 703-648-6717

O'Bryan, Don
Office of Surface Mining
1020 15th St.
TAD-TIPS
Denver, CO 80202
Phone: 303-844-3069
FAX: 303-844-2852

Oates, William C.
National Park Service
Star Route, Tahoma Wds.
Ashford, WA 98304
Phone: 206-569-2211
FAX: --

Olsen, Thomas
Bureau of Land Management
P.O. Box 25047
Denver Fed. Center
Denver, CO 80225-0047
Phone: 303-236-8857
FAX: 303-236-3508

Oser, James L.
Bureau of Reclamation
D-7600
P.O. Box 25007
Denver, CO
Phone: 303-236-6773
FAX: 303-236-6763

Otton, Jim
U.S. Geological Survey
Box 25046, MS 939
Denver Fed. Center
Lakewood, CO 80225
Phone:
FAX:

Patchett, Gary
Bureau of Reclamation
P.O. Box 9980
Tucson, AZ 85068
Phone:
FAX:

Patterson, William P.
Office of Environ. Affairs
10 Causeway St.
Room 1022
Boston, MA 02222
Phone: 617-565-6856
FAX: 617-565-6858

Paulson, Anthony J.
Bureau of Mines
315 E. Montgomery Ave.
Spokane, WA 99207-2291
Phone:
FAX:

Perera, Cynthia
National Park Service
800 N. Capitol, NW
Suite 580
Washington, DC, 20001
Phone: 202-343-1007
FAX: 202-523-5186

Peters, Douglas C.
Bureau of Mines
P.O. Box 25086
Denver Fed. Center, Bldg. 20
Denver, CO 80225
Phone: 303-236-0772
FAX: 303-236-0828

Peterson, Raymond C.
National Park Service
83 South King Street
Suite 212
Seattle, WA 98104
Phone: 206-553-4832
FAX: 206-553-0678

Pipkin, Ruth Ann
Bureau of Reclamation
P.O. Box 2005
Denver, CO 80225
Phone: 303-236-4736
FAX: 303-236-6763

Paul, David B.
Bureau of Reclamation
P.O. Box 25007
Denver, CO 80225
Phone: 303-236-3917
FAX: 303-236-5526

Paulson, Steven E.
Bureau of Mines
5629 Minnehaha Ave., S
Minneapolis, MN 55417
Phone:
FAX:

Perry, Cyndi
Fish & Wildlife Service
4401 N. Fairfax Dr, #330
Arlington, VA 22203
Phone: 703-358-2148
FAX: 703-358-1800

Peterson, Bob
Bureau of Reclamation
P.O. Box 25007
Denver Fed. Center (D-3800)
Denver, CO 80225
Phone: 303-236-8647
FAX: 303-236-0017

Petrie, Lloyd
Bureau of Mines
5629 Minnehaha Ave, S
Minneapolis, MN 55417
Phone: 612-725-4662
FAX: 612-725-4526

Podwysocki, Melvin H.
U.S. Geological Survey
913 National Center
Reston, VA 22092
Phone: 703-648-6111
FAX: 703-648-6057

Polityka, Charles S.
Office of Environ. Affairs
500 NE Multnomah St.
Suite 600
Portland, OR 97232-2036
Phone: 503-231-6157
FAX: 503-231-2361

Powell, John D.
U.S. Geological Survey
411 National Center
Reston, VA 22092
Phone: 703-648-5010
FAX:

Price, Steven E.
National Park Service
75 Spring St.
Atlanta, GA 30303
Phone: 404-331-5835
FAX: --

Reisinger, Robert W.
Bureau of Mines
P.O. Box 25086
Building 20, Denver Fed. Center
Denver, CO 80225
Phone: 303-236-5202
FAX: 303-236-4208

Rich, R. Wayne
Bureau of Reclamation
302 E. 1860 S.
P.O. Box 51338
Provo, UT 84605-1338
Phone: 801-379-1282
FAX: 801-379-1159

Rigg, Jennifer E.
Solicitor's Office
P.O. Box 25007 (D-105)
Denver, CO 80225-0007
Phone:
FAX:

Port, Patricia S.
Office of Environ. Affairs
600 Harrison St.
Suite 515
San Francisco, CA 94107-1376
Phone: 415-744-4090
FAX: 415-744-4121

Powell, Richard C.
National Park Service
P.O. Box 25287
Denver, CO 80225
Phone:
FAX:

Quint, Bob
Bureau of Reclamation
P.O. Box 61470
Boulder City, NV 89006-1470
Phone: 702-293-8132
FAX: 702-293-8146

Resnick, Joan
Bureau of Land Management
5050 N. 19th Ave., #300
Phoenix, AZ 85015
Phone: 602-336-6552
FAX: 602-336-6555

Ridley, Trude M.
U.S. Geological Survey
Denver Fed. Center-MS 946
Box 25046
Denver, CO 80225
Phone: 303-236-1373
FAX: --

Robinson, Robert H.
Bureau of Mines
P.O. Box 25086
Denver Fed. Center, Bldg. 20
Denver, CO 80225
Phone: 303-236-0423
FAX: 303-236-0238

Robison, Bill
Bureau of Land Management
HC 33, Box 33500
Ely, NV 89301-9408
Phone:
FAX:

Ross, Diane
National Park Service
2525 Gambell Street
Anchorage, AK 99503-2892
Phone: 907-257-2588
FAX: 907-257-2510

Royse, Douglas L.
Fish & Wildlife Service
143 Union Boulevard
S-405, POB 25207, Denver Fed. Center
Denver, CO 80225-0207
Phone: 303-236-2076
FAX: 303-236-4240

Salisbury, Richard
Bureau of Mines
P.O. Box 25086
Denver Fed. Center, Bldg. 20
Denver, CO 80225
Phone: 303-236-0423
FAX: 303-236-0238

Sanders, William A.
National Park Service
Appalachian Natl Scenic Trail
c/o Harpers Ferry Center
Harpers Ferry, WV 25425
Phone: 304-535-6278
FAX: 304-535-6270

Schild, Donald E.
U.S. Geological Survey
7th & C St., Bldg. Z-68
Commerce City, CO 80022
Phone:
FAX:

Roehm, Gerald W.
Fish & Wildlife Service
Bldg. 111
Rocky Mtn. Arsenal
Commerce City, CO 80022
Phone: 303-289-0232
FAX: 303-289-0579

Roy, Richard
Fish & Wildlife Service
Rocky Mountain Arsenal
Building 111
Commerce City, CO 80022-2180
Phone:
FAX:

Rumenik, Roger
U.S. Geological Survey
227 N. Bronough St.
Suite 3015
Tallahassee, FL 32301
Phone: 904-681-7620
FAX: 904-681-7650

Sanders, Ellen
National Park Service
12795 W. Alameda Pky.
P.O. Box 25287
Denver, CO 80225
Phone: 303-969-2789
FAX: 303-987-6645

Schafersman, David
Bureau of Land Management
P.O. Box 25047
Denver Fed. Center
Denver, CO 80225-0047
Phone: 303-236-8857
FAX: 303-236-3508

Schilling, Jean
U.S. Geological Survey
P.O. Box 25046
Denver Fed. Center, MS-204
Denver, CO 80225
Phone: 303-236-5900
FAX: 303-236-5900

Schmalz, Barbara
Office of Environ. Affairs
P.O. Box 250007
Denver Fed. Center, D-108
Denver, CO 80225-0007
Phone: 303-236-6900
FAX: 303-236-4093

Schottler, George
Bureau of Mines
P.O. Box 25086
Bldg. 20, Denver Fed. Center
Denver, CO 80225
Phone: 303-236-0423
FAX: 303-236-0238

Scullin, James C.
Bureau of Reclamation
P.O. Box 9332
Spanish Flat Station
Napa, CA 94558
Phone: 707-966-2111
FAX: 707-966-0409

Sekavec, Glenn
Office of Environ. Affairs
P.O. Box 649
Albuquerque, NM 87103
Phone: 505-766-3565
FAX: 505-766-1059

Seyler, David A.
U.S. Geological Survey
105 National Center
Reston, VA 22092
Phone: 703-648-4433
FAX: 703-648-5068

Shirts, Monte B.
Bureau of Mines
729 Arapeen Dr.
Salt Lake City, UT 84108
Phone: 801-584-4101
FAX: 801-584-4119

Schmidt, Robert L.
Bureau of Mines
5629 Minnehaha Ave., S.
Minneapolis, MN 55417
Phone: 612-725-4597
FAX: 612-725-4526

Scoville, Thomas A.
Bureau of Reclamation
125 South State St.
Salt Lake City, UT 84121
Phone: 801-524-6097
FAX: 801-524-5499

Seigal, Stanley
Bureau of Reclamation
P.O. Box 9980
Phoenix, AZ 85068
Phone:
FAX:

Sekayouma, Marcus
Bureau of Indian Affairs
P.O. Box 26567
Albuquerque, NM 87125-6567
Phone:
FAX:

Sheap, Fred
Bureau of Reclamation
1849 C St., NW
Washington, DC 20240
Phone:
FAX:

Skinner, Susan
Bureau of Land Management
P.O. Box 12000
Reno, NV 89520
Phone: 702-785-6570
FAX: 702-785-6602

Smart, MJ
Bureau of Land Management
P.O. Box 25047
Denver Fed. Center
Denver, CO 80225-0047
Phone: 303-236-8857
FAX: 303-236-3508

Smith, Kenneth
Bureau of Land Management
P.O. Box 25047
Denver Fed. Center
Denver, CO 80225-0047
Phone: 303-236-8857
FAX: 303-236-3508

Snyder, Bruce E.
Bureau of Reclamation
P.O. Box 11568
Salt Lake City, UT 84147
Phone: 801-524-5441
FAX: 801-524-3034

Soller, David
U.S. Geological Survey
926 National Center
Reston, VA 22092
Phone:
FAX:

Stanley, Daniel L.
U.S. Geological Survey
207 NW 2nd St.
Room 22
Ocala, FL 34475
Phone: 904-629-8931
FAX: 904-629-5996

Steckley, Robert
Bureau of Mines
Denver Federal Center
Bldg. 20
Denver, CO 80225
Phone: 303-236-5202
FAX: 303-236-4208

Smith, Bruce
U.S. Geological Survey
Box 25046, Denver Fed. Center
MS 964
Denver, CO 80225
Phone: 303-236-1399
FAX: 303-236-1425

Smith, Marie A.
Bureau of Mines
P.O. Box 25086
Denver Fed. Center
Denver, CO 80225
Phone: 303-236-0757
FAX: 303-236-0828

Snyder, Linden E.
Bureau of Mines
P.O. Box 25086
Denver Fed. Center, Bldg. 20
Denver, CO 80225
Phone: 303-236-0771
FAX: 303-236-0828

Sponaugle, Boyd
National Park Service
2525 Gambell St.
Anchorage, AK 99503-2892
Phone: 907-257-2591
FAX: 907-257-2448

Stanley, Linda
W&S
6640 MIB
Washington, DC 20240
Phone: 202-208-4457
FAX: 202-371-2815

Stein, Barry
Solicitor's Office
500 N.E. Multnomah St.
Suite 607
Portland, OR 97232
Phone: 503-231-2173
FAX: 503-231-2166

Stewart, Bill
Bureau of Mines
Spokane Research Center
East 315 Montgomery Ave.
Spokane, WA 99207
Phone: 509-484-1610
FAX: -

Stone, Heather
National Park Service
600 Harrison St.
Suite 600
San Francison, CA
Phone: 415-744-3914
FAX: 415-744-4043

Sturniolo, Fred
National Park Service
P.O. Box 37127
Washington, DC 20001
Phone: 202-343-7040
FAX: 202-523-5186

Sutley, Stephen
U.S. Geological Survey
Box 25046, MS 973
Denver Fed. Center, Bldg. 20
Lakewood, CO 80225
Phone: 303-236-2444
FAX: -

Thompson, Phillip E.
Solicitor
1849 C St., NW
Washington, DC, 20240
Phone: 202-208-6526
FAX: 202-219-1791

Tourtelot, Harry A.
U.S. Geological Survey
Box 25046, MS 911
Denver Fed. Center
Denver, CO 80225
Phone: 303-236-5438
FAX: 303-236-5448

Stewart, Robert F.
Office of Environ. Affairs
P.O. Box 250007
Denver Fed. Center, D-108
Denver, CO 80225-0007
Phone: 303-236-6900
FAX: 303-236-4093

Stroud, William P.
Bureau of Mines
P.O Box 25086
Denver Fed. Center, Bldg. 20
Denver, CO 80225
Phone: 303-236-0878
FAX: 303-236-0828

Suehowicz, William J.
Bureau of Reclamation
6850 Studhorse Flat Rd.
Sonora, CA 95370
Phone: 209-536-9094
FAX: 209-536-9652

Taylor, Willie
Office of Environ. Affairs
1849 C St., NW
Washington, DC 20240
Phone: 202-208-3891
FAX: 202-208-6970

Tiedt, Glenn
Solicitor
P.O. Box 25007
Denver, CO 80225
Phone: 303-231-5353
FAX: 303-231-5363

Tyler, Keith
Bureau of Land Management
221 N. Service Road
Moore, OK 73160-4946
Phone: 405-794-9624
FAX: 405-794-9624

Veith, David L.
Bureau of Mines
5629 Minnehaha Ave., S.
Minneapolis, MN 55417
Phone: 612-725-4709
FAX: 612-725-4526

Volkening, Larry
U.S. Geological Survey
P.O. Box 25046
Denver Fed. Center, MS205
Denver, CO 80225
Phone: 303-236-5900
FAX: 303-236-5859

Waddell, Kidd M.
U.S. Geological Survey
1745 W. 1700 South
Salt Lake City, UT 84104
Phone:
FAX:

Walters, Jim
National Park Service
P.O. Box 728
Santa Fe, NM 87504-0728
Phone:
FAX:

Wang, Carl
National Park Service
P.O. Box 25287
Denver, CO 80225
Phone: 303-987-6623
FAX: 303-969-2930

Wegrzyn, John
Fish & Wildlife Service
730 Simms St.
Suite 290
Golden, CO 80401
Phone:
FAX:

Visnapuu, Aarne
Bureau of Mines
P.O. Box 280
Rolla, MO 65401
Phone: 314-364-3169X221
FAX: 314-364-7350

Vonich, Peter
Bureau of Reclamation
2800 Cottage Way
MP-705
Sacramento, CA 95825
Phone: 916-978-5581
FAX: 916-978-5284

Wagner, William
Bureau of Land Management
324 So. State St.
Salt Lake City, UT 84111
Phone: 801-539-4062
FAX: 801-539-4074

Walters, Martha
National Park Service
P.O. Box 29022
Crissy Field--Bldg. 277
San Francisco, CA 94129
Phone:
FAX:

Watson, Brent
Bureau of Reclamation
125 South State
Salt Lake City, UT 84121
Phone: 801-524-4415
FAX: 801-524-3034

Welsh, Robert
Office of Surface Mining
1020 15th St.
TAD-TIPS
Denver, CO 80202
Phone: 303-844-4072
FAX: 303-844-2538

Wheeler, Richard
Bureau of Mines
Spokane Research Center
East 315 Montgomery Ave.
Spokane, WA 99207
Phone: 509-484-1610
FAX: -

White, Frank B.
Bureau of Mines
801 S. Fillmore
Suite 500
Amarillo, TX 79101-3545
Phone: 806-376-2672
FAX: 806-376-2633

Williams, Bradford B.
Bureau of Mines
P.O. Box 25086
Denver Fed. Center, Bldg. 20
Denver, CO 80225
Phone: 303-236-3400
FAX: 303-236-0238

Wiltshire, Richard L.
Bureau of Reclamation
D-3620
P.O. Box 25007
Denver, CO 80225
Phone: 303-236-4315
FAX: 303-236-6763

Wright, Jr., William H.
U.S. Geological Survey
915 National Center
Reston, VA 22092
Phone: 703-648-6514
FAX: 703-648-5464

Zilka, Nick
Bureau of Mines
E. 360 Third Ave.
Spokane, WA 99202
Phone: 509-353-2700
FAX: 509-353-2661

White, Allen
Bureau of Land Management
P.O Box 1869
Rock Springs, WY 82902
Phone: 307-382-5350
FAX: 700-328-6251

Whitlock, Lloyd C.
Bureau of Reclamation
P.O. Box 51338
Provo, UT 84605-1338
Phone: 801-379-1093
FAX: 801-379-1159

Wilson, Robert M.
Office of Environ. Affairs
1849 C St., NW
2340-MIB
Washington, DC 20240
Phone: 202-208-7556
FAX: 202-208-6970

Winkle, Burton
Bureau of Reclamation
P.O. Box 25007
Denver, CO 80235-0007
Phone: 303-236-8077
FAX: 303-236-0890

Zelanko, Joseph C
Bureau of Mines
P.O. Box 10807
Cochrans Mill Road
Pittsburgh, PA 15236
Phone: 412-892-6249
FAX: 412-892-6891

CONTACTS WITHIN DOI OFFICES AND BUREAUS

U.S. GEOLOGICAL SURVEY

Contacts for Hazardous Waste Issues

GEOLOGIC DIVISION

1. Geologic information for site characterization:
Geology, Geochemistry, Geophysics, Marine

Eastern Region
Nancy Milton
U.S. Geological Survey
953 National Center
Reston, Virginia 22092
703-648-6660
fax 703-648-6684

Central Region
Harry Tourtelot
U.S. Geological Survey
P.O. Box 25046, Mail Stop 911
Denver Federal Center
303-236-5438
fax 303-236-5448

Western Region
William Normark
U.S. Geological Survey
Mail Stop 919
345 Middlefield Road
Menlo Park, California 94025
415-329-5101
fax 415-329-5125

2. Inquiries about analysis of solid samples
contaminated by hazardous elements:

Paul Lamothe
U.S. Geological Survey
Box 25046, Mail Stop 973
Denver Federal Center
Denver, Colorado 80225
303-236-1800
fax 303-236-3200

ADMINISTRATIVE DIVISION

1. Inquiries about facility safety issues:
Gary Kramer, Bureau Safety Manager
U.S. Geological Survey
246 National Center
Reston, Virginia 22092
703-648-7556
fax 703-648-7414

U.S. Geological Survey, Water Resources Division
Contacts for Hazardous Materials Issues

1. Water-resources information and questions about field activities or site assessments:

Northeastern Region
Dennis Sulam
U.S. Geological Survey, WRD
Mail Stop 433, National Center
12201 Sunrise Valley Drive
Reston, Virginia 22092
703/648-5821
FAX: 703/648-4850

Central Region
William Hotchkiss
U.S. Geological Survey, WRD, CR
P.O. Box 25046, Mail Stop 406
Denver Federal Center
Lakewood, Colorado 80225
303/236-5928
FAX: 303/236-5959

Southeastern Region
D. Briane Adams
U.S. Geological Survey, WRD
Suite 160
3850 Holcomb Bridge Road
Norcross, Georgia 30092
404/409-7708
FAX: 404/409-7725

Western Region
Janet Hren
U.S. Geological Survey, WRD
Mail Stop 470
345 Middlefield Road
Menlo Park, California 94025
415/329-4447
FAX: 415/329-4463

2. Inquiries about handling and disposal of hazardous materials:

Carlos Arozarena
U.S. Geological Survey, National Water Quality Laboratory
P.O. Box 25046, Mail Stop 407
Denver Federal Center
Lakewood, Colorado 80225
303/467-8035
FAX: 303/467-8240

3. Inquiries about analysis of samples contaminated by hazardous materials:

Dorothy Walker
U.S. Geological Survey, National Water Quality Laboratory
P.O. Box 25046, Mail Stop 407
Denver Federal Center
Lakewood, Colorado 80225
303/467-8051
FAX: 303/467-8240

U.S. DEPARTMENT OF THE INTERIOR
BUREAU HAZARDOUS MATERIALS CONTACTS

Mary Josie Cain Blanchard
Chief, Division of Hazardous
Materials Management
Office of Environmental Affairs
1849 C Street, N.W. (MS/2340-MIB)
Washington, D.C. 20240
202-208-7877
202-289-7405 (fax)

Bernie Hyde
Chief, Hazardous Materials Staff
Bureau of Land Management (750)
1849 C Street, N.W. (MS/302 LS)
Washington, D.C. 20240-9998
202-653-7574
202-653-9872 (fax)

Jim Devine
Assistant Director for Engineering
U.S. Geological Survey
12201 Sunrise Valley Drive (MS/106)
Reston, Virginia 22092
703-648-4423
703-648-4466 (fax)

Kip Hagen
Chief, Branch of Maintenance
National Park Service
800 North Capitol Street, N.W (MS/580)
Washington, D.C. 20005
202-343-7040
202-523-5186 (fax)

Lew Moore
Resource Specialist
Bureau of Reclamation
1849 C Street, N.W. (MS/6530 MIB)
Washington, D.C. 20240
202-208-6703
202-208-6252 (fax) up to 10 pages
202-208-3484 (fax) over 10 pages

Cliff Haupt
Chief, Environmental Affairs
Program
U.S. Geological Survey
(SAME ADDRESS) (MS/423)
(703) 648-6826
(703) 648-5704 (fax)

Phillip Doe (D-5140)
Land Management Coordinator
Bureau of Reclamation
Dever Federal Center, Bldg. 67
6th Avenue & Kippling
Denver, Colorado 80225
303-236-8065
(303)236-3573 (fax)

MAY 1993

BUREAU HAZARDOUS MATERIALS CONTACTS (cont'd)

Pam Mathes
Division of Environmental
Contaminants
Fish and Wildlife Service
4401 N. Fairfax Drive (MS/330)
Arlington, Virginia 22203
703-358-2148
703-358-1800 (fax)

Frank Khattat
Ecologist, Division of Water
and Land Resources
Bureau of Indian Affairs
1849 C Street, N.W. (MS/4546-MIB)
Washington, D.C. 20240
202-208-3959
202-208-5493 (fax)

Jim Cook
Senior Staff Assistant, Research
Bureau of Mines
810 7th Street, N.W. (MS/6200)
Washington, D.C. 20241
202-501-9293
202-501-9957 (fax)

Bill Dockery
Petroleum Engineer
Minerals Management Service
381 Elden Street, Room 4700
Herndon, Virginia 22070
703-787-1548
703-787-1575 (fax)

Dave Guthrie
Chief, Construction
Fish and Wildlife Service
4401 N. Fairfax Drive (MS/330)
Arlington, Virginia 22203
(703) 358-1719
(703) 358-2227 (fax)

George Farris
Chief, Environmental Services
Staff
Bureau of Indian Affairs
(SAME ADDRESS) (MS/4525-MIB)
202-208-4791
202-219-1255 (fax)

Larry Miller
Chief, Office of Regulatory
Projects Coordination
Bureau of Mines
(SAME ADDRESS) (MS/5204)
202-501-9732
202-219-2490 (fax)

Bill Schmidt
Chief, Division of
Environmental Technology
Bureau of Mines
(SAME ADDRESS) (MS/6205)
202-501-9269
202-501-9957 (fax)

John Goll
Chief, Environmental Policy
& Programs Division
Minerals Management Service
(SAME ADDRESS) (Room 4300)
703-787-1656
703-787-1186 (fax)

BUREAU HAZARDOUS MATERIALS CONTACTS (cont'd)

Nancy Garrett
Assistant Director, Adminstration
Office of Surface Mining
1951 Constitution Avenue, N.W.
(MS/252-SIB)
202-208-2593
202-219-3100 (fax)

Edgar Johnson
International Programs Officer
Territorial & International Affairs
1849 C Street, N.W. (MS/4324-MIB)
Washington, D.C. 20240
202-208-6816
202-501-6381 (fax)

Kurt Gernerd
Environmental Engineer
Office of Construction Management
1849 C Street, N.W. (MS/2417-MIB)
Washington, D.C. 20240
202-208-5399
202-219-2390 (fax)

U.S. DEPARTMENT OF THE INTERIOR
OFFICE OF ENVIRONMENTAL AFFAIRS
REGIONAL ENVIRONMENTAL OFFICERS, ASSISTANTS AND SECRETARIES

BOSTON - CT,MA,ME,NH,NY,RI,VT

William P. Patterson
Andrew L. Raddant
Patricia R. Mazzarella

FAX: 617-223-8569
617-223-8565
408 Atlantic Avenue, Room 142
Boston, Massachusetts 02210-2209

PHILADELPHIA - DC,DE,MD,NJ,PA,VA,WV

Donald R. Henne
Michael T. Chezik
Carol D. Beall

FAX: 215-597-9845
215-597-5378
Custom House, Room 217
200 Chestnut Street
Philadelphia, Pennsylvania 19106

ATLANTA - AL,FL,GA,KY,MS,NC,PR,TN,SC,VI

James H. Lee
Gregory L. Hogue
Vacant

FAX: 404-331-1736
404-331-4524
Russell Federal Building, Suite 306
75 Spring Street, S.W.
Atlanta, Georgia 30303

CHICAGO - IA,IL,IN,MI,MN,MO,OH,WI

Sheila M. Huff
Vacant
Annie L. Hawkins

FAX:312-353-1051
312-353-6612
John Kluczynski Building, Room 3422
230 South Dearborn Street
Chicago, Illinois 60604

ALBUQUERUE - AR,LA,NM,OK,TX

Vacant
Glenn B. Sekavec
Susan G. LeFevre

FAX: 505-766-1059
505-766-3565
Post Office Box 649
Albuquerque, New Mexico 87103
(421 Gold SW, Room 310)

DENVER - CO,KS,MT,NE,ND,SD,UT,WY

Robert F. Stewart
Barbara M. Schmalz
Le M. Watkins

FAX: 303-236-4093
303-236-6900
P.O. Box 250007 (D-108)
Denver Federal Center
Denver, Colorado 80225-0007
(Building 56, Room 1018)

SAN FRANCISCO - AS,AZ,CA,CM,GU,HI,NV

Patricia S. Port
William C. Allan
Tracey Y. Queripel

FAX: 415-744-4121
415-744-4090
600 Harrison Street, Suite 515
San Francisco, CA 94107-1376

PORTLAND - ID,OR,WA

Charles S. Polityka
Preston A. Slegger
Kay Kier-Haggenjos

FAX: 503-231-2361
503-231-6157
500 NE Multnomah Street
Suite 600
Portland, Oregon 97232-2036

ANCHORAGE - AK

Paul D. Gates
Pamela A. Bergmann
Douglas L. Mutter
Rosemarie Braden

FAX: 907-271-4102
907-271-5011
1689 C Street, Room 119
Anchorage, Alaska 99501-5126

April 1993

NATIONAL PARK SERVICE HAZARDOUS MATERIALS CONTACTS

HEADQUARTERS OFFICE

Hazardous Waste Program
WASO 610
P.O. Box 37127
Washington DC 20013
202-343-7040

Shawn Norton, Program Manager
Cynthia Perera, Environmental Protection Specialist (EPS)
Fred Sturniolo, EPS
Helen Hossley (temporary detail)

Hazardous Waste Program, WASO-OE
12795 W. Alameda Parkway
P.O. Box 25287
Denver CO 80225
303-969-2080

Steve Hunt, EPS
Shawn Mulligan, EPS

ALASKA REGION

Alaska Regional Office
2525 Gambell Street
Anchorage AK 99503
907-257-2648

Joan Darnell, Chief, Environmental Quality Division
Kevin Keeler, EPS
Ray Martinez, Chief, Facility Design and Maintenance

MID-ATLANTIC REGION

Mid-Atlantic Regional Office
143 S. Third St.
Philadelphia PA 19106
215-597-7135

Patricia Bentley, Resource Management Specialist
Ken Sukolski, Civil Engineer
Robert Gift, Regional Environmental Coordinator

MIDWEST REGION

Midwest Regional Office
1709 Jackson St.
Omaha NE 68102
402-221-3423

Dick Fisher, Environmental Engineer

NATIONAL PARK SERVICE HAZARDOUS MATERIALS CONTACTS

NATIONAL CAPITOL REGION

National Capitol Regional Office
1100 Ohio Drive SW
Washington DC 20242
202-523-5675

Julia Hewitt, EPS
Donald Filsoof, Chief, Maintenance and Operations Engineering

NORTH ATLANTIC REGION

North Atlantic Regional Office
15 State St.
Boston MA 02109
617-223-5066

Hank Brightman, Hazardous Waste Coordinator
David Price, Maintenance Division

PACIFIC NORTHWEST REGION

Pacific Northwest Regional Office
83 S. King St., Suite 212
Seattle WA 98104
206-553-4832

Ray Peterson, Regional Safety Manager
Richard Engle, Engineer

ROCKY MOUNTAIN REGION

Rocky Mountain Regional Office
12795 W. Alameda Parkway
P.O. Box 25287
Denver CO 80225
303-969-2920

Richard Powell, Regional Safety Manager
Jack Walford, General Engineer

SOUTHEAST REGION

Southeast Regional Office
Richard B. Russell Federal Building
75 Spring St. SW
Atlanta GA 30303
404-331-5835

Steve Price, EPS
Bob Greer, Maintenance

NATIONAL PARK SERVICE HAZARDOUS MATERIALS CONTACTS

SOUTHWEST REGION

Southwest Regional Office
P.O. Box 728
Santa Fe NM 87504
505-988-6022

Jim Walters, Resource Operations
Joe Bruno, Supervisory Civil Engineer
Jan Schmitt, Environmental Coordinator

WESTERN REGION

Western Regional Office
600 Harrison St., Suite 600
San Francisco CA 94107
415-744-3914

Bill Cecil, Regional Safety Manager
Heather Stone, Hazardous Materials Coordinator
Dick Davis, Engineer
Noby Ikeda, Maintenance Division

APPALACHIAN TRAIL

Appalachian Trail Project
c/c Harpers Ferry Center
Harpers Ferry WV 25425
304-535-6278

Bill Sanders, Safety Manager

ADDITIONAL INFORMATION

Federal Facility Compliance Act of 1992

Prepared for: General Distribution

Key Point: The Federal Facility Compliance Act of 1992 amends the Solid Waste Disposal Act (SWDA) to clarify that the United States has expressly waived sovereign immunity in order that all federal agencies, facilities and employees will be subject to all of the provisions of federal, state and local hazardous waste laws and regulations. In addition, federal facilities now must reimburse the Environmental Protection Agency (EPA) for yearly inspections and states may assess service charges for permitting and inspections of federal facilities.

Potential Issues:

1. Will states assess burdensome fines, penalties and service charges against federal facilities? Will states increase inspection programs and charge the federal facilities for inspections, permitting, and studies?
2. Will this statute have a chilling effect on a land manager's willingness to perform environmental audits if the information could be used in a prosecution that might subject the manager to personal liability?
3. Will the fines and penalties be paid from agency appropriations? How will charges for EPA inspections of treatment, storage and disposal facilities and state service charges be funded?
4. Does this statute give EPA the authority to issue unilateral orders and fines against other executive agencies?

Background: Section 6001 of the SWDA, 42 U.S.C. § 6961, did not expressly waive the United States' sovereign immunity with respect to administrative orders, fines and penalties. EPA and the states claimed that with no ability to issue administrative orders and fines against federal facilities it was difficult to enforce the SWDA and the Resource Conservation and Recovery Act (RCRA). The Federal Facility Compliance Act clearly waives sovereign immunity and subjects federal facilities, departments, agencies and employees to all of the provisions of federal, state, and local hazardous waste laws and regulations in the same manner as private parties. The debates about the bill indicate that most of the compliance problems involved facilities owned by the Department of Defense and the Department of Energy.

Provisions of the Act:

Applicability: The act applies to any federal facility with jurisdiction over a solid waste management or disposal facility or site, and to any federal facility engaging in activities that result in disposal or management of hazardous waste. This definition includes the licensed treatment, storage and disposal facilities and additional sites where any disposal or management of hazardous waste takes place.

Fines and Penalties: The Federal Facility Compliance Act amends § 6001 of the SWDA, 42 U.S.C. § 6961 to include an express waiver of sovereign immunity to all substantive and procedural requirements under RCRA and SWDA, including all state, local, federal and interstate requirements. This includes administrative orders, civil and administrative penalties and fines, injunctive relief, permit requirements and service charges. The penalties and fines may be coercive or punitive and may be assessed for continuing, isolated or intermittent violations. A separate section of the act provides that EPA may issue administrative compliance orders against executive agencies, and that EPA must initiate these administrative orders in the same manner as against a private party. The Senate report indicates that by this section Congress specifically rejects the "unitary executive" theory advanced by the Department of Justice that prevented EPA from issuing administrative orders against executive agencies. The federal government is not liable for criminal sanctions.

Service Charges: Federal facilities are also liable for reasonable, nondiscriminatory service charges and fees assessed by the states for inspections, monitoring, permit issuance and renewals, studies and plans.

Personal Liability for Penalties: Federal employees are not personally liable under the Federal Facility Compliance Act for civil penalties, but a federal employee or agent can be held personally liable for criminal sanctions under any federal or state hazardous waste law.

Use of funds collected by the states: The fines, penalties and service charges collected by the states for violations of RCRA and SWDA must be used by the states for protection of the environment or to defray the costs of environmental protection and enforcement unless a state constitution or a current state law provides that the money should go into a general fund.

Effective Dates: The Federal Facility Compliance Act becomes effective immediately, with a three

year delay for certain programs run by the Department of Energy. Existing agreements, permits, administrative orders and judicial orders between the agencies and the EPA or the states are amended to waive sovereign immunity immediately, although nothing else in the agreements or orders is changed.

Yearly Inspections: The Federal Facility Compliance Act amends RCRA to provide that the EPA must conduct a yearly inspection of all treatment, storage and disposal facilities and that each federal facility must reimburse the EPA for the cost of these inspections. A narrow interpretation of this provision, and the interpretation that EPA will probably adopt, is that EPA must only inspect licensed treatment, storage and disposal facilities, as opposed to every facility where hazardous waste is handled. In addition to the EPA inspections, states with authorized hazardous waste programs may conduct yearly inspections of federal hazardous waste sites and may charge the federal facility for the cost of these inspections under the reasonable service charge provision. It is possible that a facility may be inspected by both the EPA and the state.

The next yearly inspection made by the EPA must include a comprehensive groundwater monitoring inspection unless groundwater monitoring was conducted during the previous year. The conference report indicates that this provision pertains to the SWDA only and is not intended to require groundwater monitoring to evaluate the compliance with other environmental statutes such as the Clean Water Act or the Comprehensive Environmental Response, Compensation and Liability Act.

Kristina Clark

Assistant Solicitor,
Land Use and Realty
October 20, 1992

THE COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION AND LIABILITY ACT

I. Background

1. The Comprehensive Environmental Response, Compensation and Liability (CERCLA), 42 U.S.C. 9601 et seq., was first enacted in 1980. The statute, when first enacted, was relatively short and mandated, in vague terms, the identification of sites where hazardous substances have been, or might be, released into the environment, investigation of the sites and cleanup of the sites by the responsible parties or the government.

2. CERCLA was amended in 1986 by the enactment of the Superfund Amendments and Reauthorization Act of 1986 (SARA), Pub. L. No. 99-499, 100 Stat. 1613 (1986). SARA greatly expanded the Superfund program and added several important provisions. Specifically, SARA added section 120, which makes it clear that Superfund applies to the government, and it specifies procedures applicable to cleanup of "federal facilities."

3. CERCLA has two key components. The first is a program for cleanup of hazardous waste sites. Second, a comprehensive liability scheme that enables the government to recover money it spends on cleanup of a site.

II. The Superfund Program and Process

A. The Program

1. The Superfund program is administered by the Environmental Protection Agency (EPA).

2. The Hazardous Substance Superfund, also known as the "Superfund", is a fund that provides the source of money for cleanups undertaken by EPA. The Superfund derives its revenues from taxes on crude oil, chemical feedstocks, corporate excise tax and general federal revenues. The Superfund may not be used for cleanup of a federally owned site.

3. Generally, CERCLA addresses the problem of actual or threatened "releases" of "hazardous substances" into the environment. A release is broadly defined to include spilling, leaking, discharging, pumping, pouring, emitting, emptying, injecting, escaping, leaching, dumping or disposing. A hazardous substance is defined as any element, compound, mixture, solution or substance which, when released into the environment, may present substantial danger to public health/welfare or the environment.

4. There are two types of response actions that EPA may take to address a release or threatened release: (A) A removal action is a short-term cleanup (generally less than 6 months) taken to mitigate a release of hazardous substances at a site. A removal action may only last for two years and may not exceed $2 million in cost. For example, leaking drums may be removed from a site. (B) A remedial action is a long-term measure designed to permanently eliminate a risk to human health and the environment at a site. The Superfund may only be used to conduct remedial actions at sites listed on the National Priorities List (discussed below).

B. The Process

1. Identification and Investigation - EPA has broad authority under section 104 of CERCLA to enter, inspect and obtain information regarding a release or threatened release at a site. Potential sites are brought to EPA's attention by a wide variety of methods, including citizens.

2. Preliminary Assessment - A preliminary assessment is performed at a site to define the conditions at the site and to determine whether further investigation and cleanup are warranted.

3. Placement on the National Priorities List (NPL) - A site is "scored" by EPA using the Hazard Ranking System. If a site scores at or above 28.5, it is placed by EPA on the NPL for cleanup. A site may also be placed on the NPL by a state using its "free pick". Once a site is placed on the NPL, EPA may use funds from the Superfund for activities conducted at the site. There are presently over 1,200 sites on the NPL.

4. National Contingency Plan (NCP) - The NCP specifies procedures, criteria and responsibilities for conducting response actions at a site. The NCP also contains the provisions of the Hazard Ranking System.

5. Remedial Investigation/Feasibility Study (RI/FS) - Once a site is listed on the NPL, an RI/FS must be performed at the site to determine the extent and nature of contamination, risks to health and environment, and alternative remedial measures. The RI/FS must be performed in accordance with the NCP and may be performed by either the EPA or a private party. An RI/FS can take up to two years to complete and cost $2 million. Once the study is finished, it is released for public comment.

6. Record of Decision (ROD) - The ROD contains a summary of the problems posed by the conditions at the site, identifies the possible remedies, compares the alternatives against the criteria established by the NCP, and presents the remedy selected along with the rationale for the selection.

7. Remedial Design/Remedial Action (RD/RA) - At this point, the actual design of the remedy is developed and the remedy is implemented.

III. Liability Provisions of CERCLA

A. Potentially Liable Parties

1. There are four categories of parties who may be liable under CERCLA:

    a. Current owners/operators of a facility;
    b. Past owners/operators of the facility at the time of disposal or release;
    c. Persons who arrange for the disposal, treatment, or transport of hazardous substances (commonly known as "generators");
    d. Transporters of hazardous substances who have selected the site.

2. CERLCA imposes strict, joint and several liability on each and every potentially responsible party (PRP) at a site. Strict liability is a standard of liability that does not require any showing of intent or negligence. Joint and several means that each PRP may be held liable for the entire costs of cleanup at the site. Joint and several liability will not apply if the harm is divisible. The government may recover cleanup costs and payment for damages to natural resources.

3. In order to establish a prima facie case for recovery of response costs, EPA or a private party must establish the following elements:

    a. The subject site is a "facility". A facility is defined as "any building, structure, installation, equipment, pipe or pipeline...well, pit, pond, lagoon, impoundment, ditch, landfill, storage container, motor vehicle, rolling stock or aircraft, or ... any site or area where a hazardous substance has been deposited, stored disposed of or placed, or otherwise come to be located; but does not include any consumer product in consumer use or any vessel." 42 U.S.C. 9601(9);
    b. A release or threatened release of a hazardous substance occurred at the facility;
    c. The defendant fits into one of the four categories of parties listed above;
    d. The plaintiff incurred costs in responding to the release; and,
    e. The costs are not inconsistent with the NCP.

4. Contribution claims - Under CERCLA section113(f)(1), any party who is found liable under CERCLA may seek contribution from any other person who is liable or potentially liable.

B. Defenses to liability

1. There are only limited defenses to liability under CERCLA, and the courts have narrowly construed these defenses. A party will not be held liable under CERCLA if a PRP can demonstrate that the release or threatened release is solely attributable to an act of God, an act of war, or the result of the actions of a third party to which the defendant does not have any contractual relationship. To obtain the protection of this latter defense, a PRP must establish that:

a. The release or threat of release of a hazardous substance and the resulting damages must be caused solely by an act or omission of a third party;

b. The third party's act or omission did not occur in connection with a contractual relationship (either direct or indirect) with the defendant;

c. The defendant must have exercised due care with respect to the hazardous substances; and

d. The defendant must have taken precautions against the third party's foreseeable acts or omissions and the foreseeable consequences resulting therefrom.

IV. Natural Resource Damages

Under CERCLA section 107(f), the natural resource trustees may act when there is an injury to, destruction of, loss of, or threat to natural resources as a result of a release of a hazardous substance. The natural resource trustees are the Secretaries of the Interior and Commerce, along with the Secretary of any land managing agency.

The term "natural resources" is definded to include the land, fish, wildlife, biota, air, water, ground water, drinking water supplies, and other such resources belonging to, managed by, held in trust by, appertaining to, or otherwise controlled by the United States.

The purpose of an action for recovery of damages to natural resources is to recover for any residual harm to the natural resources. Therefore, the residual harm is assessed only after the remedial action has been completed or the likely effect of the remedial action on the natural resources has been taken into account.

Sums recovered by the natural resource trustees may only be used to restore, replace or acquire the equivalent of the natural resources damaged.

Community Environmental Response Facilitation Act

Key Points: The Community Environmental Response Facilitation Act of 1992 (CERFA), P.L. 102-426, October 19, 1992, amends § 120(h) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). CERFA directs the Federal Government, before termination of Federal operations on any real property owned by the United States, to identify real property where no hazardous substance or any petroleum product or its derivatives, including aviation fuel and motor oil, was disposed of, stored (for more than one year), or released. Once real property has been identified as uncontaminated, either the EPA (in the case of sites on the Superfund National Priorities List) or the host state must review and concur in the designation at least six months before termination of Federal operations. The Federal Government is required to enter into a covenant with each purchaser or recipient of Federal land identified as uncontaminated requiring the government to pay for any cleanup work that is subsequently found to be necessary.

Issues: CERFA applies to real property owned by the United States on which it plans to "terminate Federal Government operations." No definition of this phrase appears in the statute or its legislative history. The precise definition of this phrase will be important to determine the scope of CERFA's application to DOI activities. EPA has convened a workgroup of interested Federal agencies to discuss agency interpretation and implementation of CERFA. The Solicitor's Office and client agencies participate in the workgroup. Due to the imprecise language of CERFA and the lack of consensus on provisions of the act, application of the act should be determined on a case-by-case basis for the near term.

Background: A primary purpose of CERFA is to facilitate the transfer of Federal property for economic redevelopment and thus ameliorate the adverse impact on local economies due to Federal facilities closures, especially defense base closures. Existing provisions of CERCLA §120(h) remain in effect. These require that the Federal agency provide notice in any contract for sale or other transfer of real property of any hazardous substance storage, release, or disposal on the property and a covenant warranting that the Federal Government will conduct any remedial action necessary after transfer.

CERFA became effective when passed, unlike the original CERCLA §120(h), which required implementing regulations.

Provisions of the Act:

Applicability: The act applies to "real property owned by the United States and on which the United States plans to terminate Federal Government operations." However, §3 of CERFA states that the identification and concurrence requirements will not preclude the termination of Federal government operations on real property owned by the United States.

Materials Covered: The identification required by CERFA applies to petroleum products or derivatives, including aviation fuel and motor oil, in addition to hazardous substances.

Identification and Concurrence: CERFA requires several steps to determine if lands are uncontaminated. At a minimum, CERFA review consists of: a detailed search of Federal records pertaining to the property; chain of title documents; aerial photographs that are reasonably obtainable through State or local government agencies; a visual inspection of the real property and any improvements as well as a visual inspection of adjacent property; a physical inspection of the adjacent property to the extent allowed by the owner; reasonably obtainable Federal, State, and local government records of each adjacent facility where there has been a release of any hazardous substance or any petroleum product or its derivatives which is likely to cause or contribute to a release or threatened release on the real property; and interviews with current or former employees involved in operations on the property.

Concurrence and Timing: Except for real property associated with military base closures, the identification and concurrence of EPA or State officials shall be made at least 6 months before the termination of operations on the real property. EPA will concur for sites on the Superfund National Priorities List and host States will review all other sites. States must concur or disagree with a property's designation as uncontaminated within 90 days or concurrence will be deemed to have been obtained.

Certain Leases: In the case of real property owned by the United States, on which any hazardous substance or any petroleum product or its derivatives was stored for one year or more, known to have been released, or disposed of, and on which the United States plans to terminate Federal Government operations, the agency shall notify the host State of any lease entered into by the United States that extends beyond the date of termination of government operations on the property. Notification is to occur before entering into the lease.

Amendment to Existing Provisions: Paragraph 3 of §120(h) is clarified to allow the transfer of property where long-term pumping and treating, or operation and maintenance have been demonstrated to the EPA to be operating properly and successfully. A new subparagraph is added to paragraph 3 to require deeds to contain a clause reserving to the United States access to the property if remedial action or corrective action is necessary after transfer.

Kristina Clark

Assistant Solicitor,
Lands Branch, Energy & Resources Division
April 6, 1993

ABSTRACT

P-1: BUREAU OF MINES EXHIBIT

The United States Bureau of Mines develops the scientific and mineral information basis for technology to help meet the Nation's mineral and material needs and to mitigate associated economic, human, and environmental costs including hazardous waste management.

Low-cost environmental remediation using mining and minerals technology is proving an effective and valuable tool in addressing environmental problems of all types, whether from mining or other sources.

The information in the Bureau of Mines exhibit summarizes significant technological capabilities, achievements, and research thrusts for addressing national mineral hazardous waste issues.

Research is conducted at nine research centers located at Albany, Oregon; Reno, Nevada; Spokane, Washington; Salt Lake City, Utah; Denver, Colorado; Rolla, Missouri; Tuscaloosa, Alabama; Minneapolis, Minnesota; and Pittsburgh, Pennsylvania.

Hazardous waste remediation activities are aimed at:

* Reducing the volume and toxicity of mining and mineral processing wastes.

* Identifying and remediating hazardous waste sites contaminated with heavy metals and other toxic constituents.

* Mitigating the environmental impacts resulting from active and abandoned mines.

* Providing a technical and scientific foundation for sound environmental regulations.

Waste site characterization activities include:

* Determining groundwater transportation pathlines in an underground hydrologic setting.

* Site characterization and assessment using cross-section, heavy metal analysis.

* Geotomography which permits imaging of geologic structures underground using seismic radio waves or electrical energy.

* Ground probing radar is used to detect objects underground that have contrasting electrical properties.

* Geostatic simulation to determine equiprobable images of field properties for assessing risk.

Hazardous material characterization activities include:

- Determination of the anion concentrations in liquid wastes using ion chromatography, titrimetry, and ion-selective electrodes.
- Characterization of waste rock for mineral content with X-ray diffraction and scanning electron microscopy.
- Determination of mineral associations, alteration assemblages, and morphologies of hazardous waste materials by scanning transmission electron microscopy, scanning electron microscopy, and electron microprobe.
- Characterize waste waters and mineral processing effluent for heavy metals using atomic absorption spectrophotometry and inductively coupled plasma atomic emission spectroscopy.

Problem definition/risk assessment are accomplished through:

- Reactivity experiments.
- Geochemical computer modeling.
- Review of potential treatment options.
- Cost and time concern comparisons taken from proven cleanup and developing technologies.

Examples of treatment technologies for decontamination of solids include:

- Vitrification of heavy metal-containing residues.
- Treatment and recycling of smelter wastes.
- Borehole extraction of waste materials.
- Mine tailings reclamation and site revegetation activities.
- Removal of toxic metals from contaminated soils.
- Closure of abandoned mine shafts using inverted pyramid plugs.

Examples of treatment options for contaminated liquids include:

- Prediction and control of acid mine drainage.
- Biological remediation using constructed wetlands to clean acidic mine waters.
- Removal of very low levels of metal cation contamination using "BIO-FIX" technology.

- * Waste plus waste technology to remove poisonous cyanide from waste solutions and recover valuable metals.

- * Cyanide decomposing bacteria for treatment and safe closure of spent heaps.

- * Liquid emulsion membranes for removal of metal ions.

The Bureau of Mines[1] is actively working with other government agencies in cooperative research aimed at cleaning up hazardous waste problems. These agencies include:

- * Bureau of Reclamation
- * Bureau of Indian Affairs
- * Environmental Protection Agency
- * State and Local Agencies
- * Corps of Engineers
- * Forest Service
- * Smelting and Refining Industry
- * Minerals Processing Industry
- * Federal Aviation Administration
- * U.S. Geological Survey
- * Private Sector Corporations

[1] DISTRIBUTION OF INDIVIDUAL HANDOUTS RELATED TO TOPICS COVERED IN THE BUREAU OF MINES POSTERS ARE AVAILABLE IN THE EXHIBIT AREA.

DRAFT

ASSISTANT COMMISSIONER -
ENGINEERING & RESEARCH

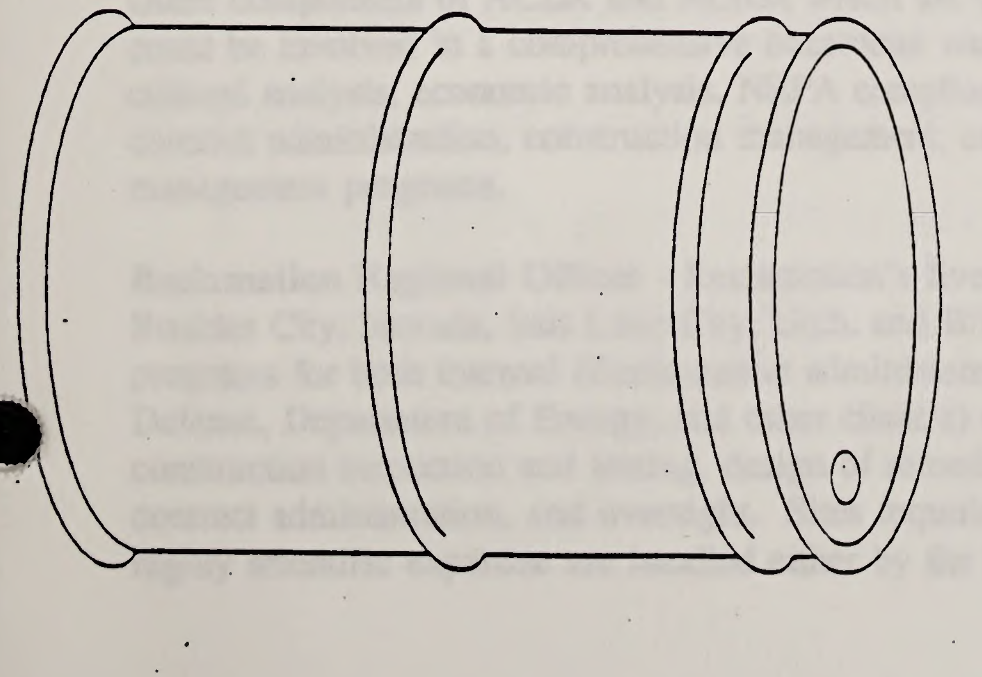
ASSISTANT COMMISSIONER -
RESOURCES MANAGEMENT

HAZARDOUS WASTE TECHNICAL SUPPORT CAPABILITIES

UNITED STATES
DEPARTMENT OF THE
INTERIOR

BUREAU OF RECLAMATION

MARCH 1993



INTRODUCTION

The U.S. Bureau of Reclamation is a large and diverse resource planning and management organization with extensive engineering and program leadership capabilities in the area of hazardous waste technical assistance. Due to the size, complexity, or national importance of our typical water resource development projects, it has traditionally been essential to ensure that our projects are properly planned and managed. To accomplish this, we have a large number of staff experienced in project planning and management, specializing in engineering, biological sciences, earth sciences, social sciences, scheduling, budgets, extensive coordination with clients and other agencies, etc. In addition, we ensure that our designs and studies utilize state-of-the-art technologies, that designs are not only functional but also cost effective, and that construction is carried out in a safe and timely manner and in full accordance with design intent. These planning/design/ construction capabilities are directly applicable to hazardous waste work that our organization would do, or to work done by others that we are charged with reviewing.

This document discusses the capabilities (in terms of hazardous waste work) of two major organizations within the Bureau of Reclamation: the **Assistant Commissioner - Engineering and Research** organization and the **Assistant Commissioner - Resources Management** organization.

The **Assistant Commissioner - Engineering and Research** (ACER) organization is responsible for directing and coordinating Reclamation's design, construction, research, geologic, dam safety, and hazardous waste technical assistance programs. ACER develops and implements policies, standards, and procedures for these activities and provides Reclamation-wide design, construction technology assistance, technical analysis of claims, and technical support services for assistance to other government agencies. This organization coordinates hazardous waste and technical assistance to other government agencies and is responsible for policy review and oversight of dam safety activities of the Department of the Interior. In addition, ACER reviews designs of major structures on Reclamation lands.

The **Assistant Commissioner - Resources Management** (ACRM) organization is responsible for directing Reclamation's programs and activities in planning, project operations, loan, and environmental compliance; cost sharing; and cost recovery. ACRM oversees compliance with policies, standards, and procedures governing these programs and activities. This organization provides technical services to the other Assistant Commissioners and the regions on resources management activities and develops and coordinates certain multiregional resources management programs.

This document is an abstract of a larger document covering the total capabilities of the ACER and ACRM organizations to perform water and related land resources investigations and studies.

The information included herein briefly describes the organizational components of the various branches, in both ACER and ACRM, and their ability to perform work associated with hazardous waste studies.

Other components of ACER and ACRM which are not directly involved in hazardous waste work, but which could be involved in a comprehensive hazardous waste study include: public involvement, social analysis, cultural analysis, economic analysis, NEPA compliance, technical writing, construction cost estimating, contract administration, construction management, construction inspection and testing, and total quality management programs.

Reclamation Regional Offices - Reclamation's five regional offices in Boise, Idaho, Sacramento, California, Boulder City, Nevada, Salt Lake City, Utah, and Billings, Montana, each have extensive hazardous waste programs for both internal (Reclamation administered lands) and external (EPA Superfund, Department of Defense, Department of Energy, and other client's) sites. Capabilities include remedial investigations, construction inspection and testing, design of remedial actions, contracting for implementation, monitoring, contract administration, and oversight. Sites requiring highly specialized chemical, toxicological or other highly scientific expertise are handled either by the Denver office or contracted to private consultants.

ASSISTANT COMMISSIONER – ENGINEERING AND RESEARCH (ACER)

Hazardous Waste Technical Assistance Office:

The Hazardous Waste Technical Assistance Office is the Reclamation-wide program office for hazardous waste technical assistance to other Government agencies. The office provides formulation, coordination, administrative support, and overview of program policies and procedures to the ACER organization, the Assistant Commissioner - Resources Management organization, and all Regional Offices when dealing with hazardous waste work for other Government agencies.

The Hazardous Waste Technical Assistance Office:

- Provides policy and procedural guidance to Reclamation organizations and recommends, as necessary, revisions to the Hazardous Waste Technical Assistance Management Plan
- Provides a single point-of-contact for other Government agencies inquiring about hazardous waste technical assistance
- Provides the required documentation to support expenditures
- Administers interagency agreements (IAG'S)
- Provides required reports and data to appropriate Reclamation organizations and other Government agencies
- Provides Industrial Health Program assistance to any Reclamation organization working on hazardous waste sites
- Reviews and approves site health and safety plans for hazardous waste sites
- Ensures Reclamation-wide consistency of Hazardous Waste Technical Assistance Program
- Has several recent accomplishments in the following programmatic areas:
    - Work for EPA through IAG's on the conventional Superfund program
    - Work for EPA on the development of the Superfund Accelerated Cleanup Model (SACM)
    - Work for the Department of Defense (DOD) at the former Strategic Air Command sites

- In partnership with the United States Geological Survey (USGS), work for DOD at Air Combat Command and Air Force Material Command bases

- Respond to requests from other Interior agencies

- Work for the Department of Energy (DOE) in the Environmental Restoration and Waste Management Program

- Work for the Department of Agriculture in cleanup of over 7,000 mine tailings sites for which the U.S. Forest Service is responsible

The Hazardous Waste Technical Office is the initial point of contact for the services provided by the ACER and ACRM organizations. The overall ACER and ACRM hazardous waste technical capabilities are summarized below and are addressed in more detail in succeeding sections on specific ACER organizations.

- Program coordination
- Financial administration
- Industrial hygiene personnel
- The ability to provide a Federal presence/oversight for hazardous waste activities
- Site characterization
    - Development of geologic and material exploration programs
    - Drilling and sampling with a wide variety of equipment and technologies
    - Geophysical investigations and Remote sensing techniques
    - Surveying
- Geologic/geotechnical evaluations
    - Geologic/geohydrologic evaluation
    - Geotechnical evaluation/remediation of hazardous waste sites
    - Ground-water modeling
    - Seismotectonic evaluation and seismic analysis of nuclear storage facilities and other projects
- Laboratory and field testing
    - Soil testing (both laboratory and in-situ)
    - Field screening for contaminants
    - EPA Level III chemical analytical services
    - Pilot testing of treatment systems

- Environmental studies
    - Environmental and fisheries studies
    - Aquatic toxicology evaluations
    - Preparation and review of environmental impact statements
- Data collection and planning studies
    - Design data collection
    - Planning studies
    - Applicable or relevant and appropriate requirements' research
    - Real estate (appraisal, acquisition, and relocation assistance)
    - Economic analysis
- Health and safety capabilities
    - Preparation and review of safety plans
    - Hazardous waste safety training and medical surveillance database for tracking and maintaining certification
- Project management
    - Central accounting system and budget management for hazardous waste work
- Data management/information systems
    - Project management office for central point of contact, administration of interagency agreements, ensuring consistency, etc.
- Quality assurance
    - Development and review of quality assurance programs
    - Value engineering
- Technical reviews
    - Preparation and review of hazardous waste reports (work plans, remedial investigation feasibility study reports, design submittals, etc.)
    - Ability to hire independent consultants for advice and review
- Remediation design
    - Preparation of detailed plans and specifications for remediation plans
    - Storage facility design (lined and capped repositories, underground excavations, etc.)
    - Geosynthetics design (membranes, liners, etc.)
    - Slurry trench cutoff wall design
    - Stabilization techniques including soil-cement, grouting, and soil mix-in-place
    - Containment/removal alternatives evaluation and design

  - Treatment plant design for contaminated water
  - Air stripping tower design
  - Tailings dams evaluation and remediation
  - Mine drainage remediation
  - Three-dimensional computer modeling and drawing production by CADD
  - Specifications/solicitations preparation, review, printing, and distribution

- Instrumentation

  - Design of instrumentation for hazardous waste sites
  - Monitoring and evaluation of instrumentation data

- Estimating and scheduling

  - Design and construction scheduling and tracking
  - Cost estimating (including independent Government estimates)

- Construction management/support

  - Advice on constructability of various design alternatives
  - Contract administration
  - Claims analysis
  - Construction inspection/oversight/management/materials testing

- Research

  - Research and development
  - Interagency coordination and technology transfer

Contact Person: Gerry Bowles
Telephone: 303-236-8646

Civil Engineering Division: Plant Structures Branch

Environmental and structural engineers, architects, and civil engineers to perform a variety of work related to hazardous waste activities including:

- Prepare designs and specifications for:
  - ▸ Water treatment facilities (industrial, potable)
    - ▸▸ Wellhead Treatment Composite Correction Program for Small Communities
    - ▸▸ Lidgerwood Arsenic Removal in North Dakota
    - ▸▸ Butz Landfill Alternate Water Supply
  - ▸ Waste water treatment facilities
    - ▸▸ Central Arizona Project Pumping Plants
    - ▸▸ Yuma Desalting Plant
  - ▸ Desalting facilities
    - ▸▸ Yuma Desalting Plant
    - ▸▸ Feasibility-West Basin Desalting Demonstration Plant
    - ▸▸ Small Community Water Treatment-Desalting Technology Program
  - ▸ Removal of hazardous material from water
    - ▸▸ Leadville Treatment Plant in Colorado
    - ▸▸ Warren Air Force Base trichloroethylene (TCE) removal
    - ▸▸ Fairchild Air Force Base TCE removal
    - ▸▸ Vandenberg Air Force Base Underground Storage Tank
    - ▸▸ North Side Pumping Division, Minidoka Project
    - ▸▸ Review of designs for Odessa Chromium II, Yak Tunnel, and Eagle Mine Superfund sites
  - ▸ Wetlands mitigation and replacement
  - ▸ Hazardous waste remediation design

Contact Person: Jim Hill
Telephone: 303-236-9075

Electrical and Mechanical Engineering Division: Electrical Branch

Work related to hazardous waste activities includes:

- Water treatment and desalting plants such as the Leadville Water Treatment Plant in Colorado and Yuma Desalting Plant in Arizona
  - Hazardous waste disposal such as Fairchild Air Force Base
- Complete electrical and electronic design of electric powerplants, pumping plants, irrigation systems, and distribution systems including:
  - Design of controls
  - Metering
  - Relaying
  - Data acquisition
  - Alarm systems for both centralized and unit applications

Contact Person: Vacant position
Telephone: 303-236-9324

Electrical and Mechanical Engineering Division: Mechanical Branch

Work related to hazardous waste activities includes:

- Special designs, such as:
  - Maintenance platforms and hoists for use inside large pipes
  - Prototype coal hoist that utilizes an air and water mixtures to lift coal for mining
  - Designs for underwater installation of mechanical equipment
  - Pore extraction vessel and mapping platform for vertical shafts for Yucca Mountain Project
  - Air stripping towers for toxic waste applications
  - Design and analysis for integrating alternative energy production (solar, wind, etc.) with existing water resource facilities
  - Modernizing and rehabilitating mechanical equipment systems
- Complete engineering studies, design, construction, support, and inspection for mechanical features associated with:
  - Desalting and water treatment plants (Yuma Desalting Plant and Lidgerwood Water Treatment Plant for arsenic removal)
  - Fish handling facilities and water temperature control devices

Contact Person: A.E. Rickett
Telephone: 303-236-9144

Construction Division:
Construction Management Branch

- For completed designs, either by Reclamation or private sector A&E firms, Reclamation has extensive experience in the preparation and/or analysis of construction CPM schedules.

- Technical review of contractors proposal for negotiated contracts and Requests for Proposals (RFP's):
    - ▸ Review for constructability.
    - ▸ Perform technical design review to ensure that the projects is constructable as designed and will meet the requirements.
    - ▸ Review for construction efficiencies.

- Provide site reviews of construction contractor's activities:
    - ▸ Review of construction contractor's safety program and implementation.
    - ▸ Inspection of construction contractor's quality and adherence to the design specifications.
    - ▸ Respond to technical problems that may arise during construction.

- Technical review and evaluation of proposed contract modifications and change orders. Technical review and evaluation of contractor claims.

- Assist in construction close out and project startup. Reclamation's construction division has extensive field experience in project startups, and can provide technical training on the plant equipment.

Contact Person: James T. Lane
Telephone: 303-236-8335

Construction Division:
Engineering Support Branch

- Development of preliminary cost estimates for budgeting and funding purposes.

- Based upon designs completed internally or by private sector A&E firms, Reclamation can finalize complete construction specifications, review, print, and distribute to prospective contractors.
  - Considered by many to be some of the best in the industry.
  - Capability to handle all Federal Acquisition Regulation advertisement requirements.

- Prepare Independent Government Cost Estimates (IGCE's) for designs prepared internally or by private sector A&E firms. These estimates can be either detailed labor-material-equipment estimates or unit price estimates. Detail estimates are prepared using computer software. Both types of estimates are supported by Reclamation's construction costs database.

- Costs and pricing reviews of contractors proposal for negotiated contracts and Requests for Proposals (RFP's):
  - Review cost and pricing data to ensure accurate and fair costs to government, and ensure that the Government is not buying more quality and quantity than required to meet the project requirements.

- Preparation of IGCE's in the evaluation and negotiations of contract modifications change orders, and contractor's claims. Provide technical and cost assistance to the Contracting Officer during negotiations for contract modifications and claims.

Contact Person: Ellis M. Bowers
Telephone: 303-236-6914

Geotechnical Engineering and Geology Division: Geology Branch

Work related to hazardous waste studies includes:

- Formulates and monitors geotechnical/geological investigations for delineation and evaluation of foundation conditions and site characterization

- Evaluates and analyzes geological data, or plan and direct other specialists to perform such studies
- Executes/oversees field activities for site characterization and data collection, evaluation, portrayal of geological conditions, and assists in geotechnical issue identification, analysis and evaluation, including:

  - Field mapping
  - Rock and soil classification
  - Subsurface explorations
  - Developing geological/geotechnical design and construction considerations
  - Presentation of data and interpretations for planning, design, specifications, and reports
  - Hazardous and toxic waste (H&TW) site characterizations and investigations
  - Seepage studies

- Designs, performs, and provides oversight and review functions for in-house and contract, surface and borehole geophysical surveys to determine subsurface conditions, seepage characteristics, foundation properties and modulus estimates, cavity prediction, and water-basin stratigraphy

- Provides technical assistance for review of documents, reports, and contracts

- Major engineering geology projects including:

  - Site characterization studies for Yucca Mountain Project, Nevada (principal investigators and staff for cooperative studies with USGS for DOE)

  - Vandenberg, Warren, and Fairchild Air Force Bases (H&TW)

  - Krejci Dump Site and Lehigh Portland Cement, Ohio; Eagle Mine, Colorado; and Odessa Chromium, Texas (H&TW for National Park Service [NPS] and EPA)

  - Superconducting Super Collider; Weldon Springs, Missouri (H&TW geology/geotechnical and geophysical reviews)

- Major seismotectonic projects including:

  - Evaluation of Quaternary faulting for Yucca Mountain Project, Nevada (principal investigators and staff for cooperative studies with USGS for DOE)

- Major engineering geophysics projects including:
    - Geophysical applications for site characterization studies for Yucca Mountain Project, Nevada (principal investigators and staff for cooperative studies with USGS for DOE)

Contact Person: R.H. Throner
Telephone: 303-236-6905

Geotechnical Engineering and Geology Division: Geotechnical Engineering and Embankment Dams Branch

Work related to hazardous waste technical studies includes:

- Hazardous waste analysis/design/oversight
  - Prepare and/or review geotechnical portions of designs and specifications for water resource and environmental projects
  - Prepare concepts/design of instrumentation programs and data collection
  - Perform geotechnical studies and analyses, including developing and interpreting exploration and lab testing programs, of a wide range of projects including:
    - Earth and concrete dams (both new construction and rehabilitation)
    - Canals, pipelines, and related features
    - Structure foundations
    - Underground excavations
    - Tailings dams
    - Hazardous waste sites
    - Yucca Mountain Project (nuclear disposal site)
    - Landslides
    - Natural soil and rock slopes
    - Instrumentation of non-dam structures (e.g., Yucca Mountain Nuclear Waste Site, Superconducting Super Collider, powerplants, etc.)
- Geosynthetics design
- Rock mechanics analysis and design

Contact Person: F.G. McClean
Telephone: 303-236-3854

Research and Laboratory Services Division: Materials Engineering Branch

Work related to hazardous waste technical studies includes:

- Project management
- Perform remedial investigations
    - Health and safety plan preparation
    - Sampling plan preparation using human health risk-based criteria
    - Field geotechnical testing using the electronic cone penetrometer
    - Field sampling of soil, soil vapor, and water
    - Field gas chromatograph analytical testing
    - Computer modeling of subsurface contaminant transport and fate
    - Site characterization
    - Data analysis and report generation
- Perform treatability studies
    - Bench-scale laboratory environment
    - Treatability study needs assessment
    - Experimental design preparation
    - In-house chemistry laboratory services
    - Data analysis and report generation
- Perform feasibility studies
    - Development and screening of alternatives
    - Detailed analysis of alternatives
- Perform remedial design
- Soils laboratory services
    - Routine analytical studies (compaction, strength, permeability)
    - Special analytical studies (batch sorption, column sorption, etc.)

Contact Person: J.S. Pierce
Telephone: 303-236-5989

Research and Laboratory Services Division: Materials Engineering Branch—Field Operations Team

Work related to hazardous waste technical studies includes:

- Geoprobe soil gas sampling vehicle for screening volatile organic compounds such as UST sites, GC, headspace, soil sampling, water sampling, XRF
- Cone penetrometer, 20-ton and drill rig deployed—cone, piezocone, resistivity cone, water sampling (bat, hydropunch, wellpoint) (e.g., Warren AFB, Krejci Dumpsite)
- Technical specialists in drilling and in-situ testing technologies for review of remedial investigations work, sampling, and quality assurance plans
    - ▸ EPA EMSL direct push research
    - ▸ ASTM standards development with USGS/EPA on drilling methods, monitoring wells, and geoenvironmental water sampling
    - ▸ USCE laser induced florescence sensor
- Technical specialists in soils classification for engineering purposes providing "hands on" training of the unified soil classification system; we are the only entity providing this training in the United States
- Technical specialists in earth construction practices; consulting on earthwork methods including processing, use of additives such as bentonite, lime, or cement; national leaders in control testing development; technical specialists in clay cap or liner construction
    - ▸ Clay cap test fill, Lehigh Portland Cement Company, Mason City, Iowa; technical assistance for EPA Region VII
    - ▸ Aladdin Plating Site, ARCS removal soil density claim and field testing technical assistance for EPA Region III
- Performing research on site characterization for ground-water modeling; developing public domain software "UNCERT" to generate three-dimensional block models for ground-water modeling based on hard and soft field data using advanced stochastic methods.
    - ▸ Recognized by EPA-EMSL as leading site characterization uncertainty analysis software
- Engineering and technician staff qualified for HT&W field work with 48-hour OSHA certification and respirator fits

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Contact Person: Jeff Farrar
Telephone: 303-236-6081

Research and Laboratory Services Division: Applied Sciences Branch

Work related to hazardous waste technical studies includes:

- Perform analytical services of all types, particularly those related to hazardous waste problems
- Perform environmental and fisheries studies
- Develop wetland restoration, design, functioning, and enhancement programs
- Develop pesticide application methods, as well as pesticide residue monitoring
- Perform aquatic weed control and toxicology evaluation
- Perform wildlife resources research
- Perform petrographic examinations and evaluations
- Perform water quality/limnological research
- Provide chemical analysis, data evaluations, and research investigations using tools such as x-ray diffraction, atomic absorption, and mass spectrometry, etc.
- Investigate wellhead treatment of brackish water for municipal use
- Perform studies to assist small communities in meeting Safe Drinking Water requirements
- Provide consultation on all water treatment matters within Reclamation's jurisdiction and conduct laboratory and field pilot tests to confirm reliability of selected desalting and water treatment processes
- Provide pilot plant evaluation of desalting processes for waste water reclamation
- Apply remote sensing and geographical information system (GIS) technologies to meet information needs; provide typical applications of remote sensing and GIS in agriculture, natural vegetation, meteorology, wildlife and fisheries management, water quality, hydrology, and geology
- Direct pretreatment and desalting testing leading to the present Yuma Desalting Plant configuration
- Prepare laboratory equipment specifications for the Desalination Research Development and Training Center at Al Jubail, Saudi Arabia
- Recently initiated Reclamation's Desalting Technology Program consisting of a 7-year plan for expanded research, technology transfer, and technical assistance

- Perform process evaluations of heavy metal removal of arsenic for Lidgerwood, North Dakota, and the Yak Tunnel and Eagle Mine in Colorado
- Recently performed research on selenium and nitrate removal and received patents on the processes
- Recently developed photovoltaic-powered electrodialysis process for the Navajo Nation
- Aquatic toxicity evaluations - hazardous waste sites
- Environmental instrumentation
- Integrated pest management program development
- Revegetation and erosion management of disturbed areas
- Hazardous waste investigations
- Fisheries resources management/research
- Aquatic ecology for reservoir and lake management
- Laboratory chemical analysis
- Field screening for hazardous materials
- Water treatment research
- Hazardous waste site work plan review
- Airborne videography
- Cartography
- Global positioning systems
- Thermography
- Contract photogrammetry

Contact Person: D.L. King
Telephone: 303-236-5991

Quality Management Office:
Quality Assurance Office

Work related to hazardous waste technical studies includes:

- Develops, implements, and then verifies effectiveness of quality assurance programs for Reclamation
- Develops quality assurance program and project plans
- Develops quality management procedures
- Develops and conducts quality assurance training for staff
- Performs surveillance and quality management reviews of programs
- Facilitates corrective actions to alleviate program nonconformances and deficiencies

This office recently:

- Developed, implemented, and then verified effectiveness of quality assurance program supporting investigations of nuclear waste disposal sites (e.g., site characterization for waste repository - Yucca Mountain Project)
- Developed, implemented, and then verified effectiveness of quality assurance program supporting hazardous waste remediation projects (e.g., Krejci Dumpsite Remedial Investigation Feasibility Study)

Contact Person: J.L. Kinney
Telephone: 303-236-0527

Quality Management Office:
Quality Assurance of Chemical Analysis Office

Work related to hazardous waste technical studies includes:

- Coordinates formulation and implementation of quality assurance/quality control (QA/QC) program for chemical analysis
- Provide guidance and monitor compliance of data collection activities to Reclamation-wide QA/QC policy for chemical analysis
- Perform annual laboratory system and performance reviews
- Provide technical support in QA/QC procedures for defensible sample collection and chemical analysis for data gathering
- Provide work plan and laboratory systems guidance and review

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Contact Person: J.C. Ellis
Telephone: 303-236-4291

ASSISTANT COMMISSIONER – RESOURCES MANAGEMENT (ACRM)

Resource Investigations Policy and Oversight Division: Departmental Irrigation Drainage Program

Work related to hazardous waste studies includes:

- Coordinates technical reviews and responses for program documents (reconnaissance and detailed study reports)
- Manages and directs planning activities to remediate the identified irrigation drainage-related impacts to fish and wildlife resources, including migratory birds and endangered species
- Manages and directs implementation of the corrective action(s)

This program recently:

- Evaluated existing data which resulted in identifying the scope of study and defining the specific problems for Middle Green River Basin Study, Utah; Kendrick Remedial Evaluation, Wyoming; and Stillwater National Wildlife Refuge, Nevada
- Listed remedial options available to solve the problems and began identifying the criteria to formulate and evaluate alternatives for Middle Green River Basin Study, Utah; and Kendrick Remedial Evaluation, Wyoming
- Prepared a preliminary assessment of factors that affect the planning activities for Stillwater National Wildlife Refuge, Nevada
- Prepared and proposed a data sampling program to continue to collect data to determine if remedial planning is warranted for the Salton Sea, California

This program:

- Provides interagency coordination for national programs
- Directs and manages interdisciplinary teams to accomplish formulation and evaluation of alternatives, documentation of plan formulation, and NEPA compliance

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Contact Person: Anthony Cappellucci
Telephone: 303-236-8311

Resource Operations Policy and Oversight Division: Water and Power Operations Branch

Work related to hazardous waste studies includes:

- Coordinate, advise, consult, and assist in the operation of Reclamation's existing projects
- Specific areas of expertise include:
  - Pesticide management, use, and disposal
  - Hazardous material management on Reclamation lands
  - Disposal of hazardous materials at TSD facilities
- Conducting hazardous materials reviews
- Conduct reviews related to hazardous materials management; pesticide use proposals; radio frequency renewals; and project operation and maintenance activities
- Coordinate inventory and disposal of PCB's and other hazardous wastes, and the inventory and removal of underground storage tanks

Contact Person: Hank Sandhaus
Telephone: 303-236-1061

Earth Sciences Division:
Resource Suitability Branch
Water Quality Section

Work related to hazardous waste studies include:

- Prepare water quality studies associated with irrigation development, municipal and industrial use, and general water supply development
- Conduct water quality studies for environmental documents, site characterizations, and feasibility studies
- Monitor and analyze water quality data for streams and reservoirs to estimate future water quality changes that result from remedial actions
- Develop and adapt models for streams and reservoirs to estimate future water quality changes that result from remedial actions
- Provide hazardous waste site investigations, site characterizations, remedial investigations, and feasibility studies (e.g., Warren Air Force Base and Krejci Dump)
- Prepare special studies to estimate salinity impacts of project development and studies to evaluate benefits of potential salinity control projects
- Prepare studies on groundwater quality (fate and transport) and geochemistry
- Develop and apply models of groundwater contaminant fate and transport and geochemistry (e.g. Durango Pumping Plant Hydrogeochemical Site Characterization)
- Review and provide technical assistance for water quality studies associated with the Department of the Interior's National Irrigation Water Quality Program for toxics (e.g., Middle Green River and Kendrick projects) and hazardous materials and waste contamination.

Contact Person: Robert George
Telephone: 303-236-3777

Earth Sciences Division:
Resource Suitability Branch
Land Suitability Section

Work related to hazardous waste activities includes:

- Provide technical support in soil sampling, laboratory analysis, and data interpretation for hazardous waste sites and evaluate impacts of toxic substances at such sites. The section currently has five soil scientists that are qualified to work on Superfund sites. Four members of our staff have field experience sampling hazardous waste sites.

- Provide guidance and perform review for soils investigations to assess the potential for creation of hazardous drainage return flows caused by irrigation

- Provide expert consultation and review capability for hazardous waste sites, soil sampling programs, and work plans

- Administer and operate the Interregional Soils and Water Laboratory, which provides chemical and physical laboratory analyses on soils, sediments, and water to support land and water resources planning and operations investigations

- Chemical and physical analysis of soils, water, and sediments, including:

    - Water: Specific conductance, pH, total dissolved solids, chloride, calcium, magnesium, sodium, potassium, boron, silicon, sulfate, nitrate, and orthophosphate

    - Soil: Salinity (1:5, ECe), pH, water-holding capacity, mechanical analysis (texture), exchangeable sodium percentage, settling volume, cation exchange capacity, and saturated paste extracts

    - Sediment: Percent sand, silt, clay; total sediment, turbidity

    - Trace element analysis of soil water extracts, water, ammonium acetate extractions of soil, and soil (EPA 3050 digestion). ICP scan includes over 25 elements. AA unit and ion chromatograph analysis also available.

- Provide data quality analysis and control services to evaluate non-Reclamation laboratories

- Provide standard soil and water samples, laboratory replicates, spiked samples, and blanks for data quality evaluations

- Provide technical services for data automation and land resources mapping using geographical information systems (GIS) (e.g., ARC/INFO)

- Drill truck and operator capable of undisturbed soil core sampling to about 10 feet and rotary drilling to about 25 feet in most unconsolidated soils. A Giddings probe mounted on a 4WD pickup provides good mobility on sites with poor access.

Contact Person: Stan Conway
Telephone: 303-236-8384

The Resource Suitability Branch has recently:

- Prepared special soils investigations relating to characteristics that may result in hazardous return flows under irrigation (e.g., Trace Element Analysis Report, Animas-La Plata Project, Canyon Ferry Arsenic Studies, Lake Andes Wagner, Marty II Demonstration Program, Red Lake Trace Element Assessment, and more than 20 additional trace element assessments)
- Provided technical support for soils and water quality sampling plans and map preparation (Krejci Dump Site, Ohio—hazardous waste)
- Participated in field soil sampling on Smelter Hill and Old Works Superfund sites (Anaconda, Montana), the Aspen Residential Soil Sampling Program, and the Krejci Dump Site hazardous waste studies.
- Participated in planning studies for the Irrigation Drainage Program, evaluated data and identified alternatives which protect public health and fish and wildlife resources from impacts associated with irrigation drainage return flows (e.g., Middle Green River, Salton Sea, and Kendrick projects)
- Prepared water quality sections of Durango Pumping Plant Hydrogeochemical Site Characterization and Addendum at Durango UMTRA Site.
- Prepared water quality sampling plans for Warren Air Force Base and Krejci Dump Site.

Contact Person: Keith Eggleston
Telephone: 303-236-8383

Earth Sciences Division:
Ground Water Branch
Geohydraulics Section

Work related to water hazardous waste activities includes:

- Investigate and design remediation for ground-water systems contaminated with hazardous waste
- Develop ground-water investigation programs and, upon request, perform field investigations for a wide variety of ground-water related problems or opportunities (e.g. supply, conjunctive use, safe yield studies)
- Complete complex analyses of ground-water flow and contaminant transport using numeric modeling techniques
- Investigate the potential for artificial ground-water recharge and recovery
- Design wells and well fields for a wide variety of purposes
- Prepare large-scale ground-water supply studies using multilayer numeric models supported by GIS
- Design testing programs and complete field testing and data analyses of complex sites requiring detailed lateral and vertical distribution of aquifer characteristics
- Model the flow of contaminated sites to demonstrate use as a construction site
- Conduct peer reviews of proposed ground-water remediation sites for EPA

Technical capabilities of the branch include:

- Construction dewatering design
- Wellhead protection studies
- Computer programming of complex analytical procedures and modification of existing codes

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Contact Person: Rod TeKrony
Telephone: 303-236-8070

Earth Sciences Division:
Ground Water Branch
Drainage/Seepage Section

Work related to hazardous waste studies includes:

- Conduct ground water investigations in the top 50 feet of the soil profile
- Analyses of ground water occuence, fluctuations, and movement in response to climatic, geologic and cultural conditions
- Analyses of ground water salinity and concentration and movement of salts within the soil profile under saturated and unsaturated conditions
- Design subsurface drain systems for control of ground water in the 0 to 25 feet depth range
- Preparation of construction specifications for subsurface drains
- Provide technical consultation for construction, operation, and maintenance of subsurface drains
- Provide seepage analyses for canals, ponds, and embankments in cooperation with the Geohydraulics Section
- Provide shallow ground water analyses for developing and managing wetlands
- Model shallow ground water systems

Contact Person: Glen Sanders
Telephone: 303-236-8089

Earth Sciences Division:
Surface Water Branch

Work related to hazardous waste studies include:

- Conduct hazardous waste site investigations, baseline risk assessments, site characterizations, remedial investigations, and feasibility studies for air-quality and surface water resources.
- Develop and maintain technical standards, guidelines, and procedures for scientific methods used to evaluate hazardous waste-air quality rules.
- Develop Air Pathways Analysis (APA) for hazardous sites to identify air issues requiring further investigation.
- Maintain a collection of historical climatological data for hazardous waste sites to determine the optimum site for instrumentation to monitor air quality and to determine the downwind areas of concern.
- Review and conduct probable maximum flood studies for reservoirs and hazardous waste facilities.
- Develop air quality monitoring programs and sampling systems.
- Screen developed technologies resulting from Memorandum on Development and Screening of Alternatives (MDSA) for air media.
- Complete complex analyses of air contaminant transport of stationary sources using numeric modeling techniques.
- Develop flood frequency analyses for design of roads, bridges, dams, canals, pipelines, and flood protection structures.
- Perform water surface profile studies for natural and manmade channels.
- Perform sediment yield analyses used for sizing reservoirs, diversion dams, and pumping plants.
- Perform hydraulic and sediment transport studies used for assessing stream channel stability.
- Perform channel morphology studies used for predicting long-term channel and riparian zone changes.
- Perform hydrologic data collection, retrieval, and analysis for hazardous waste sites.

Contact Person: Jim Thomas
Telephone: 303-236-3776

General Sciences Division:
Ecology Branch

Work related to hazardous waste studies includes: .

- Provide environmental analyses and technical assistance on fisheries, wildlife, wetlands, and other biological and ecological issues
- Develop and maintain technical standards, guidelines, and procedures for scientific methods used to evaluate biological and environmental analyses
- Develop applicable or relevant and appropriate requirements (ARAR's) for hazardous waste sites
- Provide environmental analysis for endangered species, fisheries, wildlife, and other biological systems
- Collect environmental information and maintain data and analyses in order to better respond to requests for this information
- Develop and review methodologies for the purpose of assessing environmental effects
- Initiate and conduct environmental research
- Provide technical assistance on water quality compliance and spill prevention, containment, and control (SPCC) management
- Monitor air and water quality problems

Contact Person: Jay Hokenstrom
Telephone: 303-236-8399

Activity Management and Reports Division: Activity Management Branch

Work related to hazardous waste activities includes: .

- Manage technical services provided to regions in accomplishing their NEPA compliance, planning, operations, water conservation, and special programs
- Managing Reclamation interdisciplinary teams to perform studies such as: Krejci Dump Site Hazardous Waste Removal Study; Central Valley Project (CVP), drainage investigations; Animas-La Plata Project; CVP and Friant Division contract renewals; Sacramento Basin fish habitat improvement study
- Manage all assigned activities requiring an ACRM interdisciplinary team, including team organization
- Develop service agreements with clients for work to be performed by the Denver Office
- Maintain liaison and consultation with other Reclamation offices; Federal, local, and State agencies; clients or cost-sharing partners; consultants and contractors; and the general public to ensure objectives are accomplished
- Schedule, direct, and monitor team progress and funds expended to ensure conformance with the service agreement
- Ensure that products are consistent with clients' needs while satisfying technical and policy guidelines

Contact Person: Richard Schaefer
Telephone: 303-236-8687

NEWSLETTERS

NATIONAL PARK SERVICE

NEWSLINE - Hazardous Materials Management and Waste Update
Address:
National Park Service - HMMWE Unit
15 State Street, Boston, MA 02109

The National Park Service Hazardous Waste Program also publishes articles in:

NPS Engineering and Safety Services Division Newsletter.

Current and Innovative Technologies

Geoanalytical Capabilities Related to Hazardous Materials and Environmental Contamination

D.E. Detra and L.P. Gough
U.S. Geological Survey, Branch of Geochemistry
MS 973, Box 25046, Denver Federal Center
Lakewood, Colorado 80225

The work of USGS scientists reflects the public's concern for responsible resource management and environmental stewardship. The Branch of Geochemistry conducts basic and applied science that is the basis for understanding environmental processes and produces information that is the basis for environmental management decision making.

The Analytical Chemistry Services Group (ACSG) of the Branch of Geochemistry has been at the forefront of analytical inorganic chemistry for the analysis of earth-science materials for over four decades. The emphasis of the ACSG has been to develop and implement analytical technologies that enable Branch geochemists and environmental scientists to most effectively solve problems related to geochemical processes and rock-water interactions as they apply to environmental issues. The laboratories are staffed with over 60 chemists, research chemists, and laboratory technicians, who routinely prepare and analyze over 40,000 earth-science materials annually for major, minor, trace, and ultra-trace inorganic constituents. Total- and partial-element determinations are made using a variety of instrumental techniques including: X-ray fluorescence spectrometry, X-ray diffraction, instrumental neutron-activation analysis, atomic-absorption spectrometry, ICP-AES, ICP-MS, and ion chromatography. Routine analytical techniques used by the laboratories have been validated by the Branch quality assurance staff who continually monitor data quality.

The Branch of Geochemistry initiated a standard reference materials (SRM) program in 1962 to develop reference materials which are relevant to the analysis of a variety of environmental and geologic sample media. As a result of this effort, Branch analysts have produced and chemically characterized 31 standard reference materials for domestic and international distribution. Of the 31 SRM's that have been produced, the Branch has prepared several on-site reference materials for environmental studies and currently uses these materials for in-house QA/QC purposes. When these materials were created, total-element analysis in combination with selected extraction procedures to evaluate element availability in the secondary environment were emphasized. In addition to the production and characterization of USGS SRM's, the Branch has cooperated with the National Institute of Standards and Technology (NIST) to develop and certify environmental SRM's. Cooperative efforts have included the development of sediments, sludge, fly ash, and contaminated soil reference materials.

Environmental research is designed to monitor, understand, and predict geochemical landscape patterns and processes in both natural and human-altered environments. Whether the processes being examined occur naturally, such as fluids moving through mineralized rock, or are the result of human activities, such as factory effluent moving through an aquifer low-temperature, geochemical principles can be applied to both.

Specifically, USGS environmental geochemistry research seeks to:

Monitor (describe) the geochemical environment. Studies focus on areas that are geochemically altered, either naturally (mineralized) or by human activities. A first step is to define geochemical baselines by using statistically based sampling methods and then use the results to determine how "different" the area is compared to other areas. Another use of this type of information is to establish data bases necessary for the assessment of future potential changes. For example, the degree of contamination of a coastal salt marsh that is receiving industrial metals can be determined today, and changes over time can then be monitored by repeating the study in the future.

Understand (interpret) existing environmental problems. This is accomplished by (a) studying how chemical elements are distributed in landscape materials by conducting broad-scale geochemical surveys, and (b) studying the processes by which major- and trace-elements are mobilized from landscape materials, transported through the environment, taken up by plants and animals, affect plant and animal nutrition and health, and ultimately deposited back in some geologic "sink." Recently, concern over selenium in aquatic wildlife refuges in the western United States developed because human irrigation activities enhanced the mobilization of this element from marine shales and concentrated it in field drain water that ultimately flowed into the refuges. In California's San Joaquin Valley, subsequent build-up of selenium through the aquatic food chain at the Kesterson Refuge resulted in selenium toxicity in wildlife.

Predict (model) environmental problems using information from multidisciplinary approaches. Drainage from abandoned mines in Colorado is currently being studied and categorized by geologic terrain. The goal is to predict the geochemical characteristics of drainage from new mines that may be proposed. This type of information will be useful in developing pre-mine plans that will save development costs and environmental degradation, and will lead to more appropriate methods of reclamation.

USGS Reference Material

Identifier	Sample Type	Collection Location	Supply*	Year Distributed
G-1	Granite	Rhode Island	E	1951
W-1	Diabase	Virginia	E	1951
AGV-1	Andesite	Oregon	~~A~~ E	1967
BCR-1	Basalt	Oregon	E	1967
DTS-1	Dunite	Washington	A	1967
G-2	Graite	Rhode Island	A	1967
GSP-1	Granodiorite	Colorado	E	1967
PCC-1	Peridotite	California	A	1967
BHVO-1	Basalt	Hawaii	E	1976
MAG-1	Marine Mud	Gulf of Maine	A	1976
QLO-1	Quartz Latite	Oregon	A	1976
RGM-1	Rhyolite	California	A	1976
SDC-1	Mica Schist	Washington, D.C.	A	1976
SCo-1	Shale	Wyoming	A	1976
SGR-1	Shale	Colorado	A	1976
STM-1	Nepheline Syenite	Oregon	A	1976
BIR-1	Basalt	Iceland	A	1984
DNC-1	Dolerite	North Carolina	A	1984
W-2	Diabase	Virginia	A	1984
NOD-A-1	Manganese Nodule	Atlantic Ocean	A	1980
NOD-P-1	Manganese Nodule	Pacific Ocean	A	1980
SDO-1	Shale	Kentucky	A	1991
CLB-1	Coal	Maryland	in progress	
DGPM-1	Gold Ore	Nevada	"	"
BSK-1	Sediment	California	"	"
GSP-2	Granodiorite	Colorado	"	"

*, A - available E - supply exhausted

POSTER SESSION:Currrent and Innovative
Spatial Technologies and Approaches

DIGITAL COLLECTION AND DISPLAY OF SURFACE ELECTROMAGNETIC DATA FROM LANDFILL SITES IN NORTH CAROLINA

BERG, Steven A. and CARDINELL Alex P., U.S. Geological Survey, 3916 Sunset Ridge Rd.,
Raleigh, North Carolina, 27607

Collection of digtital surface electromagnetic(EM) data and integration of these data with a geographic information system(GIS) combines two powerful technologies in hazardous waste site analysis. These methods provide technology for storing and processing large data sets, spatially defining the data within standard coordinate systems, and relating the data to known features within and around the area of study. Spatial displays of the instrument response over known buried features can also help with data interpretation.

Shallow frequency domain electromagnetic data were collected at several landfill investigation sites at Fort Bragg, North Carolina with a portable EM instrument(EM-31) connected to a data logger. Prior to data collection, an orthogonal grid was constructed and each grid intersection was marked with a flag. The grid intersections were surveyed and the grid corners were tied to a known coordinate location.

The orthogonal grid lines were traversed in a forward and reverse direction with the instrument and the data were collected at one second intervals, which resulted in a two to three foot spatial interval. As each grid intersection marker was passed, a digital marker point was added to the data file. Each line of data was uploaded to a computer, combined with other lines and assigned an x and y grid coordinate. A GIS point coverage was generated in grid coverage units(in these examples we use feet). This coverage was transformed using GIS software into a standard projection system(State Plane Coordinates) by projecting the corners of the constructed grid into the surveyed coordinates.

In previous studies, a 200 by 200 foot grid spacing usually resulted in a data set of 50 points or less. Digital data collection, which requires no more time than data collection for previous studies and can be completed by one individual, has increased the data set size and resolution by an order of magnitude. Lost and misplaced data has decreased because the data sets become part of larger spatial data bases. When an anomaly is found, the increased resolution allows quick and accurate spatial interpretation of the instrument response.

The data set can also be related to other digitized features within the study area because it has a standardized coordinate system. Several cultural features(overlays) have been digitized and the instrument response is plotted in relation to coverages of reinforced concrete slabs, buildings and roads, and elevation. When a buried feature has been identified from a GIS coverage, data collection over the known feature combined with the spatial display of the instrument response can aid future interpretations.

Hazardous Waste Management at the U.S. Geological Survey, National Water Quality Laboratory

Carlos Arozarena, Kathleen Galloway, Clarence Nichols, Joe Santillanes, and
Roger Smith, U.S. Geological Survey, WRD, NWQL, Denver, Colorado

Hazardous waste management at the U.S. Geological Survey, National Water Quality Laboratory (NWQL) is of supreme importance. Receiving in excess of 45,000 samples per year, the laboratory must be capable of disposing of samples received by the laboratory as well as waste generated during the analysis process. Many of these samples contain preservatives such as mercuric chloride and potassium dichromate. During disposal, the mercury and chromium preservatives added to the samples are removed. Ion-exchange techniques are used extensively to reduce the amount of metal-containing waste sent to disposal facilities, greatly decreasing waste volumes and disposal costs.

To assist in tracking of waste streams, the NWQL uses a PC-based database. The use of a database allows NWQL personnel to examine the amount of waste generated by waste type, specific analytical line, and program. Trends in waste generation aid in identifying where efforts in waste minimization should be focused.

By using ion-exchange technology and database waste stream tracking, the NWQL will continue to minimize the amount of waste generated by the laboratory and reduce waste disposal costs.

BLM Library
Denver Federal Center
Bldg. 50, OC-521
P.O. Box 25047
Denver, CO 80225

1. Sample Receiving

The National Water Quality Laboratory receives more than 45,000 water samples per year. These samples come from all 50 states and U.S. protectorates. Each sample can contain several bottles of water for analysis depending upon the tests requested. The samples are checked for accuracy, bar coded, and then made available for analysis.

Some analyses require that water sent to the laboratory contain a preservative such as mercuric chloride or potassium dichromate. Other samples are acidified. These samples must be disposed of properly after analysis.

2. Analysis of Samples

The National Water Quality Laboratory analyzes for various inorganic and organic constituents. Inorganic analyses include inorganic metals and trace elements, cations, anions, and other analytes. Organic analysis examines pesticides, herbacides, industrial organic compounds, and other analytes. The laboratory produces approximately one million data points per year.

3. Sample Storage and Removal

Samples are retained for a period of 180 days. After this holding period, a list of samples requiring additional analytical work is examined. This list is called the "save list." All samples which are to be retained are removed from the shelves and placed in a holding area. The remaining samples are removed from the shelves and readied for disposal.

4. Inorganic Waste and Sample Disposal

After removal for the shelves, the samples are are segregated by perservative. Samples containing mercuric chloride, potassium chromate, and acidified samples are segregated from nonpreserved samples. The are brought to a neutral pH, and then pumped through a metal removal system. The metal removal system uses an ion exchange system to trap the mercury and chromium. After metal removal, the sample solution is disposed. After the ion exchange resin has been used up, it is removed and sent for disposal.

Laboratory line waste containing mercury amd chromium is also treated by the metal removal system for disposal.

5. Lab Packing and Organic Waste Disposal

Wastes are identifed as to location, quantity, and contents. This information is recorded on internal disposal record forms by the waste generator. The forms are then routed to disposal personnel. These forms provide disposal personnel with all the information necessary to properly dispose of the material.

Waste to be lab packed is segregated, inventoried, placed in containers with absorbant materials, and prepared for shipment to disposal sites.

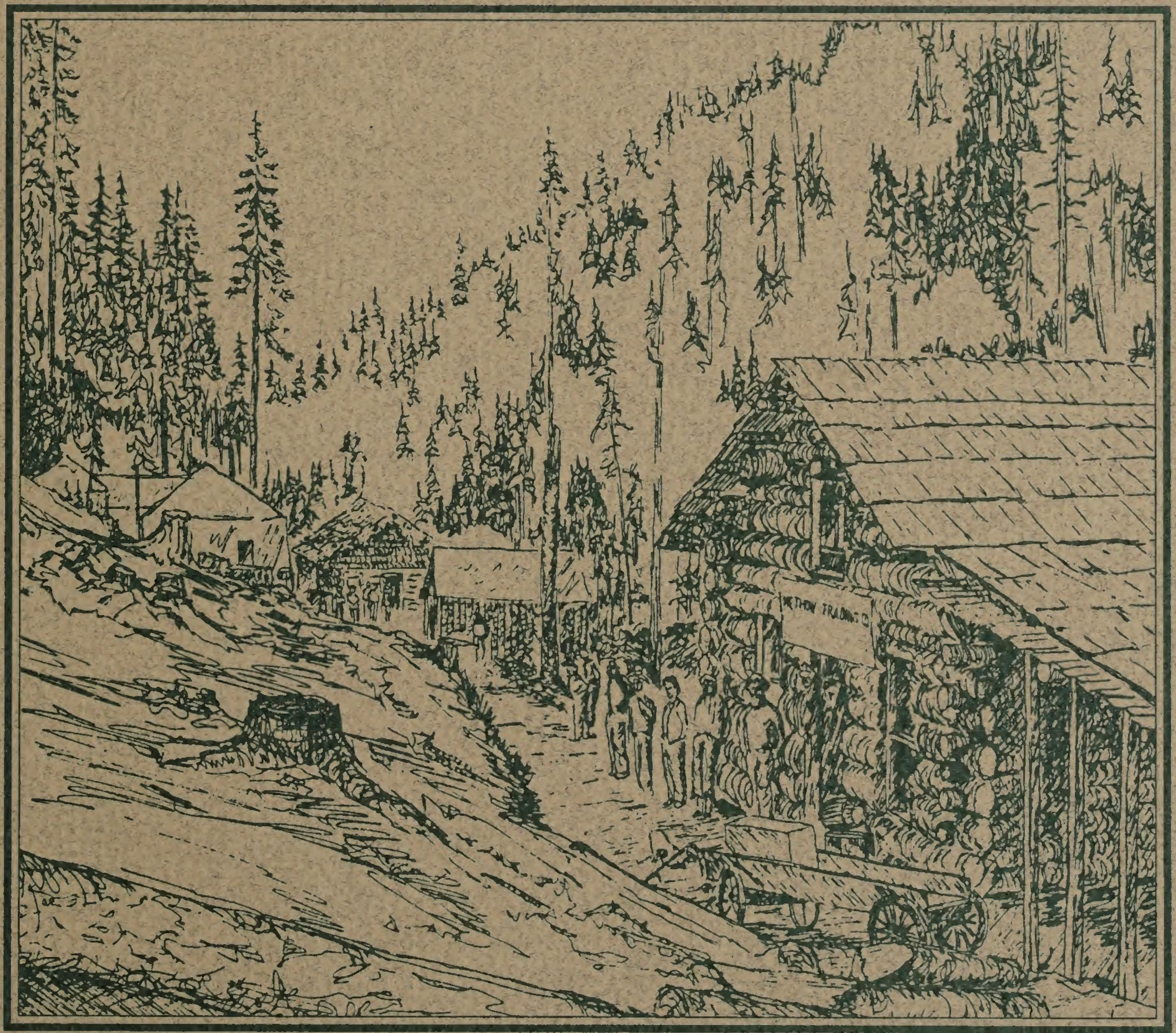
Waste from specific procedures is collected in specified "satellite accumulation areas" within the laboratory. These wastes are then transfered to larger containers for bulk disposal.

6. Data Collection and Recordkeeping

Data from the disposal process is collected and placed in a database. The data for internal waste streams is collected from manifests completed and sent with the waste for disposal. This information is used to determine the amount of waste generated by each waste stream, department, program, and the entire lab as a whole.

This information aids in determining which processes could benefit from minimization efforts and helps in determining which waste streams can be reduced in a cost effective manner.

THE BUREAU OF MINES MINE SITE CHARACTERIZATION PROGRAM



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THE ISSUES

Government agencies, including those within the Department of the Interior (DOI), face a rapidly expanding, costly liability for the cleanup of hazardous waste sites. This is particularly true for public lands containing abandoned mining and milling sites. The Environmental Protection Agency (EPA), in its 1985 report to Congress, estimated the total volume of existing mine wastes to be more than 50 billion tons. A 1991 report prepared for the Western Governors' Association indicates the total number of sites to be hundreds of thousands and the potential total cost of reclamation to be billions of dollars.

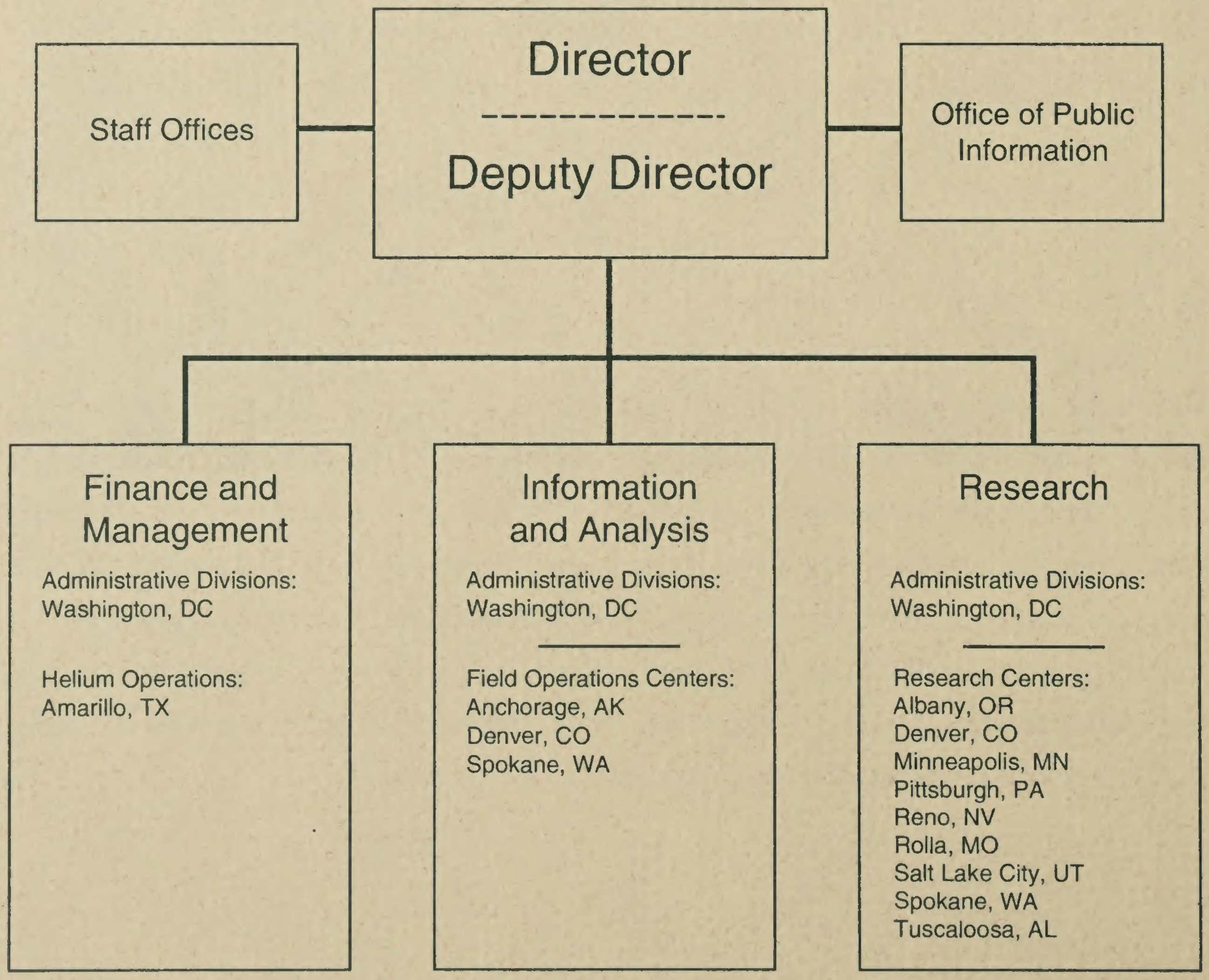
Attempts to accurately define the scope of the problem in greater detail have been marginally successful. Bureau of Mines records show that at least 200,000 mining-related sites, most abandoned or inactive, exist nationally. The obviously hazardous sites, especially those in proximity to urban areas, have been targeted under Superfund. Of the more than 1200 sites on the National Priorities List (NPL), 47 are directly related to mining. However, of the remaining mine sites, those that deserve priority attention and, just as importantly, those which can be ignored, are largely unidentified. Most of these sites are in rural areas, often on or surrounded by public lands, and thus the responsibility (CERCLA, Section 120) of Federal land-management agencies. In the absence of a clear understanding of the scope and severity of the hazards associated with inactive and abandoned mining-related sites, the public remains highly concerned about the true risks posed by the often visible wastes.

Mining and minerals-related sites can be very complex physically and chemically due to the broad spectrum of ore types, processing techniques, mining methods, and metal recoveries that were emphasized during the life of an operation. Traditional site characterization methods are often ineffective for large volume wastes that contain generally low, but highly variable, metal contents; especially those that occur in areas which by definition (mining districts) have high levels of naturally occurring metals. Accordingly, the quantities and areal distribution of contaminated material, the exact nature of contamination, and the risks to the environment are often inadequately defined. Appropriate remedial decisions and actions are the result of accurate site characterization. If recent, preliminary Bureau studies are indicative, two percent of the total number of sites could require detailed examination to accurately determine their risk to the environment.

SOLUTIONS - BUREAU OF MINES STUDIES

The basic problem —what's there/ how much is there/ what are the options for dealing with it — is fundamentally similar to the process of mineral discovery and extraction and lends itself to adaptations of techniques used by the Bureau and industry for mineral exploration, mining, and beneficiation. The Congressional Office of Technology Assessment, in its October 1989 report entitled Coming Clean: Superfund's Problems can be Solved, noted the unique expertise of the Bureau of Mines for permanent resolution of problems at sites contaminated with metals and recommended a Bureau Superfund support program. In response, the Bureau developed a coordinated approach that involves both the Research Directorate and the Information and Analysis Directorate.

The Mine Site Characterization Program of the Information and Analysis Directorate, which addresses the problem of accurate definition of the environmental risks posed by mine sites, is based upon decades of experience in mineral exploration and ore reserve estimation. Efforts are focussing on developing mine-site-specific characterization procedures, regional inventory strategies, risk assessment protocols, and cost estimating systems; testing developed methods at selected sites/ areas; and providing assistance to government agencies dealing with abandoned mine problems.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Field Operations Centers: Anchorage, AK
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Research
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Research Centers: Albany, OR
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Spokane, WA
Tuscaloosa, AL

The Environmental Technology Program of the Research Directorate, which addresses the remediation solutions required for mine sites, is based upon decades of experience in mining and mineral processing. Efforts are centered on development of new technology that supports reprocessing of past wastes, minimization of wastes from current mining and processing, decontamination of hazardous waste disposal sites, treatment of acid mine drainage, detoxification of metallurgical wastes, and mitigation of damage caused by mine subsidence.

The coordinated Bureau approach provides customer agencies with a complete evaluation package including determination of the threat posed by mine wastes, more accurate and cost-effective site investigation procedures, improved hazard assessment protocols, and effective remediation alternatives.

EXPERTISE/EXPERIENCE

The Bureau's Mine Site Characterization Program team is located at the Western Field Operations Center (WFOC), 360 E. Third Avenue, Spokane, Washington 99202 (Tel. No. 509-353-2700). This team includes broad expertise in related sciences and advocates a multidisciplinary approach to problem solving.

❖ *Mine Site Location* - The large number of inactive and abandoned mine sites requires the use of efficient, accurate screening methods. Decades of conducting mineral resource investigations of active and inactive mines, prospects, waste dumps, and processing facilities on and near public lands has generated a computer database (MILS/MAS) containing details on location, geologic setting, operational character, and size for each site. Data can be selectively retrieved via a variety of search parameters and compared to other data via GIS. Using this database, a computer-based procedure to categorize mine sites as to their potential risk to the environment was designed and applied to National Forest lands in Washington in 1992. A manual has just been published to guide investigators performing inventories of abandoned mine/mill sites.

❖ *Geochemical Sampling* - Knowing the extent and magnitude of contamination on a site is critical to determining the need for and choice of remediation techniques. Team experts have designed and carried out numerous sampling programs for mine workings, waste dumps, tailings ponds, soils, surface streams, alluvium, and groundwater. Quality assurance and control (QA/QC) plans and documentation have been prepared when appropriate. In the past couple of years, a broad spectrum of studies have been conducted in the Coeur d'Alene River basin (ID).

- *Hydrology* - Water is the contaminant pathway most often of concern. Team hydrologists have expertise in saturated and unsaturated fluid flow analysis, contaminant dispersal mechanisms, water well installation, and water quality monitoring. Detailed studies were conducted in 1990 at the Silver Mountain Superfund Site (WA).

- *Geophysics* - Geophysical methods provide a non-invasive means to characterize a site. Team geophysicists have conducted detailed surveys using state-of-the-art electromagnetic, magnetic, radiometric, and seismic methods. In 1992, surveys were conducted on tailings at the Charles Dickens mill (ID).

- *Geostatistics* - Effective remediation requires an accurate description of the site. Geostatistical techniques are used to delineate the spatial distribution of metals in hosts, ascertain the significance of anomalous values, and determine the representativeness of sample data. Recently, team members prepared a 3-D model for heavy metals in tailings at the Midvale Superfund Site (UT).

- *Cost Analysis* - It is important that all environmental projects be based on an accurate estimation of costs. Bureau staff have gained international recognition in the costing and financial analysis of various aspects of the mineral industry. Several costing models concerning environmental controls on mining and processing wastes and the socioeconomic impacts of mineral development have recently been developed.

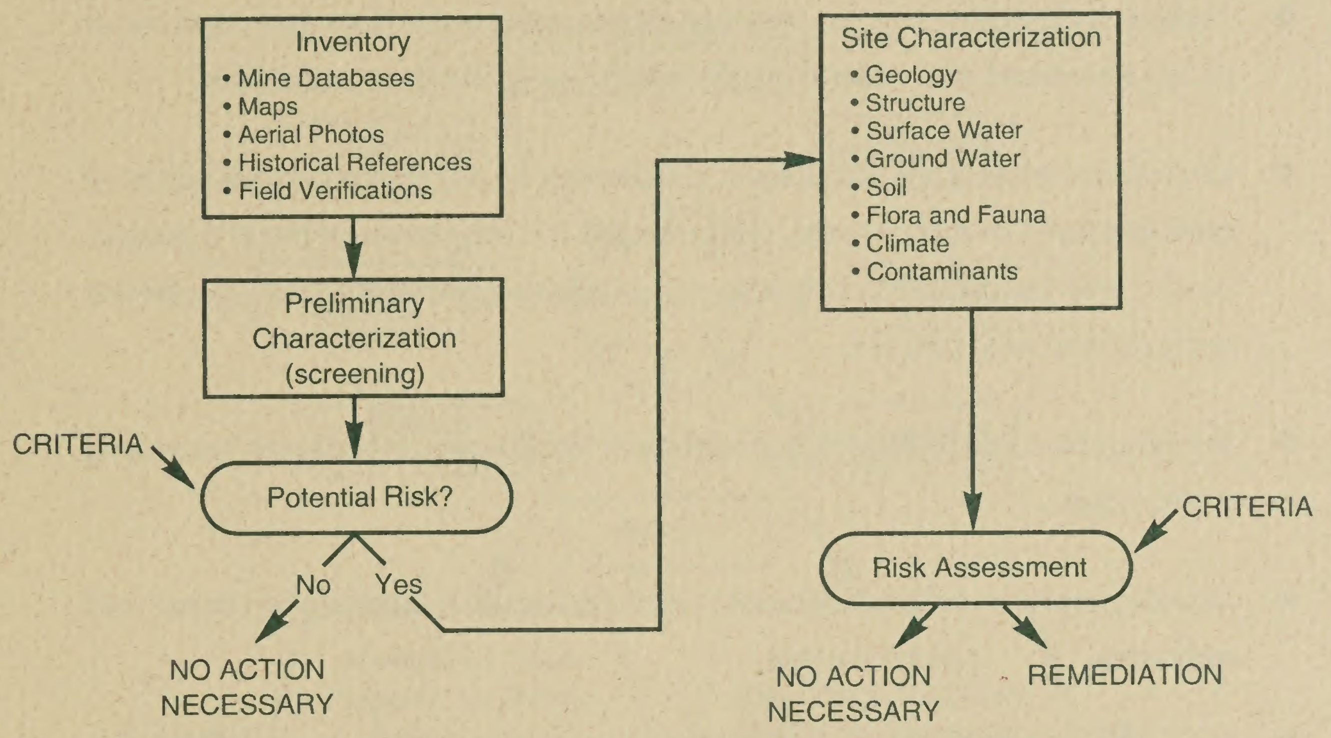
- *Biology* - Because inactive and abandoned mines are often in a rural setting, flora and fauna, not humans, are potentially more at risk. Team biologists and environmental scientists have field and laboratory experience in ecosystem evaluation, toxicity testing, stream characteristic surveys, habitat analysis, and risk assessment.

- *Engineering Analysis* - An environmental assessment strategy that considers the operational aspects of mines and mills is important to success. Bureau mining engineers have produced publications on reclamation, bonding, waste management, and mine/mill design.

APPROACH

The Mine Site Characterization Program has two primary objectives: first, to assist government agencies concerned with inactive and abandoned mines; second, to conduct investigations on a broad spectrum of topics related to the process of and procedures for characterizing individual mine sites or groups of sites and assessing risk.

Regional Inventory/Site Characterization Process



Methodology development studies will include:

- Investigation of strategies for prioritizing mine sites as to their environmental risk that rely on generally available or readily obtainable minerals data. The EPA Hazard Ranking System does not produce consistent, accurate results for mine sites.

- Design of efficient, representative environmental sampling methodologies, including sampling pattern design, sample extraction and reduction, statistical data validation, and data reduction and analysis.

- Development of decision trees to standardize the selection of site characterization strategies.

- Refinement of existing Bureau cost estimating systems to predict costs of remediation.

- Evaluation and refinement of geophysical methods for detection and mapping of contaminants, delineation of wastes, and assessment of groundwater contaminant plumes.

- Investigation of background levels of metal concentrations in groundwater, surface waters, and soils in areas of known ore deposits.

- Assessment of what processing and analysis of spectral data obtained via remote sensing can contribute to mine site characterization and regional environmental studies.

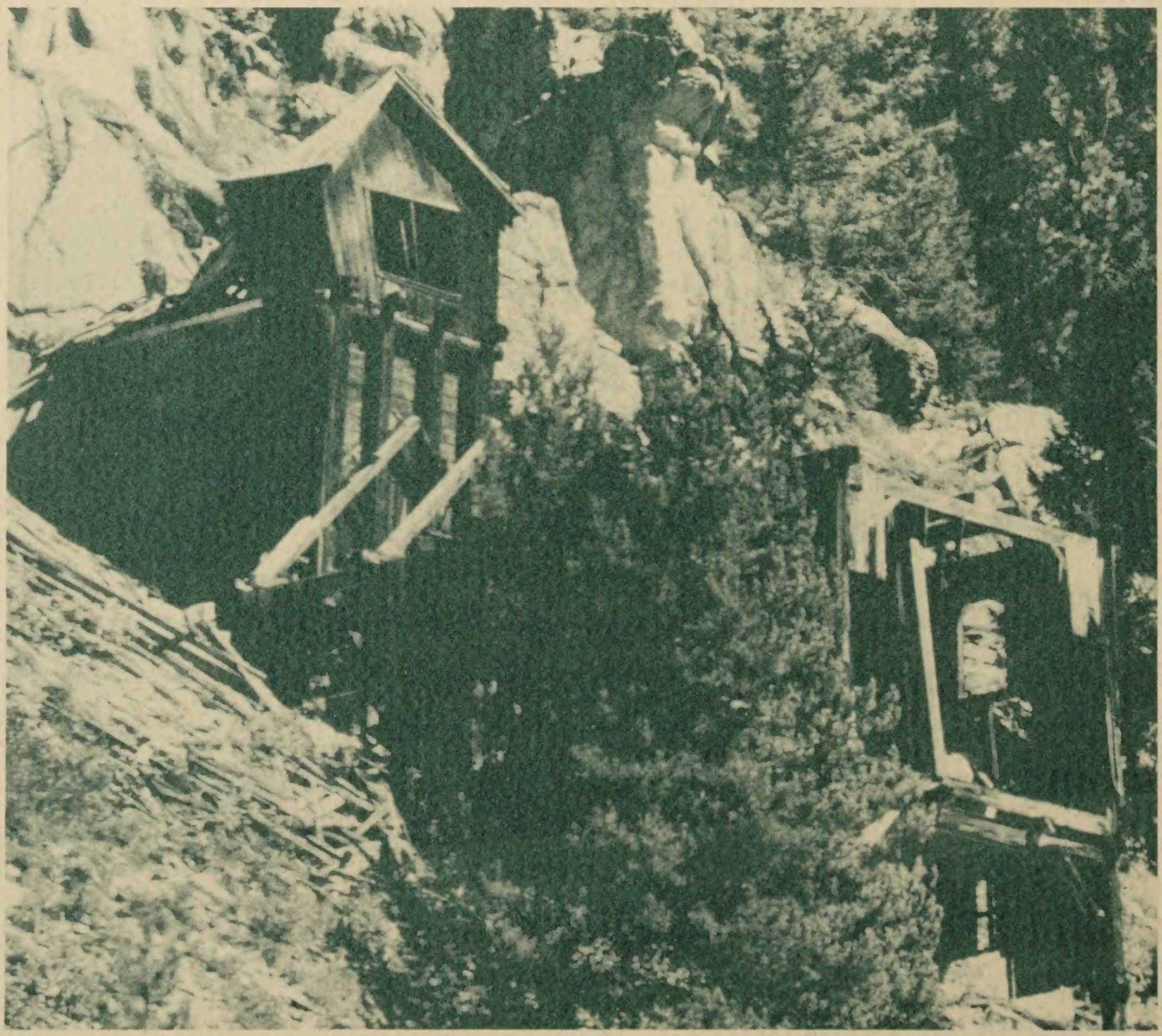
- Determination of the relative contributions of multiple point and non-point pollution sources in drainage basins that contain old mining districts.

- Testing techniques and/or instruments to reduce the time and expense of doing saturated and unsaturated zone investigations at mine sites.

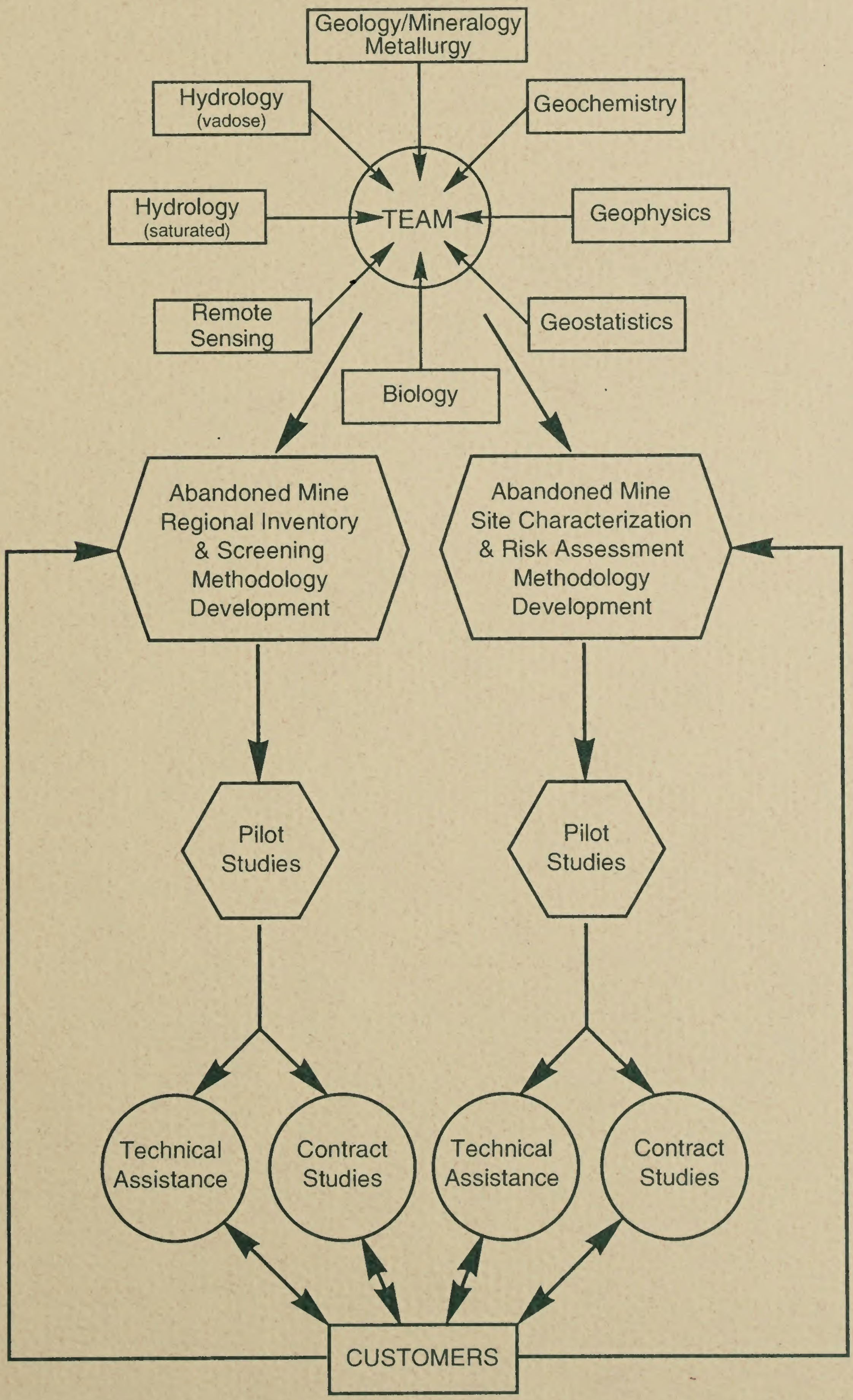
- Evaluation of models that allow prediction of the spatial distribution of contaminants in mine waste, the potential for migration of those contaminants, and the possible impact on the existing situation from proposed remediation alternatives.

- Investigation and testing of geostatistical techniques to evaluate hazards at waste sites.

- Development of risk assessment criteria relevant to abandoned mine and mill sites.



The Program will produce integrated, interdisciplinary protocols, not a best protocol for a single discipline. Developed protocols are tested, refined, and retested at selected mine sites and mining districts. Projects are formulated through consultation with other governmental agencies and sites for methodology development and pilot studies are chosen based in part on the priorities of those agencies. Products are tailored to both meet the needs of other agencies as well as those of the Bureau of Mines.



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AML INVENTORY FORM

Part I - Pre-Field Data (Side 1)

PAGE 1 **OF**

SITE NUMBER

DATE

1) PROPERTY NAME:

Alternate names:

MILS Sequence No.:

MRDS No.:

BOM Mineral Property File No.:

State ID No.:

EPA ID No.:

2) OWNERSHIP:

What is the current ownership of the site? (Check one)

Federal ☐ Indian ☐ State ☐ County ☐ Municipal ☐ Private/Patented ☐

Unknown ☐ Other

If the owner is known, fill in the following information:

Name or Agency:

Address:

Telephone Number: - -

) LOCATION DATA:

Fill in location information as available.

State:

County:

Township: **N S**

Range: **E W**

Section:

Section Subdivision:

Meridian:

Latitude:

Longitude:

Elevation:

Specify units for elevation: Feet ☐ Meters ☐

Map Name:

Map Scale:

1:250,000 Quadrangle:

4) HISTORICAL DATA:

Check all that apply.

Type of Operation:

Surface ☐ Underground ☐ Surface-Underground ☐ Mineral Location ☐ Placer ☐

Prospect ☐ Dredge ☐ Processing Plant ☐ Well ☐ Unknown ☐ No Data ☐

Status of Operation:

Past Producer ☐ Explored Prospect ☐ Raw prospect ☐ Unknown ☐

Developed Prospect (greater than 300 meters of workings) ☐

Commodities:

Arsenic ☐ Cadmium ☐ Copper ☐ Lead ☐ Mercury ☐ Zinc ☐

Other (specify):

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AML INVENTORY FORM

Part I - Pre-Field Data (Side 2)

PAGE 2 OF

SITE NUMBER

DATE

4) HISTORICAL DATA (Continued.)

Check all that apply:

Acid Producers or Indicator Minerals:

Arsenopyrite ☐ Chalcopyrite ☐ Galena ☐ Marcasite ☐ Sphalerite ☐ Sulfide ☐
Iron Oxide ☐ Limonite ☐ Pyrite ☐ Phyrrotite ☐ Stibnite ☐

Size/Production:

Indicate the amount of ore produced in metric tons (mt):

Small (0-10,000 mt) ☐ Small-Medium (10,000mt-250,000mt) ☐ Medium (250,000mt-500,000mt) ☐
Medium-Large (500,000mt-1,000,000) ☐ Large (Over 1,000,000mt) ☐

Mill Method:

Amalgamation ☐ Arrastre ☐ Gravity ☐ Crusher (only) ☐ Heap Leach ☐ Leach ☐
CIP (Carbon-in-Pulp) ☐ Cyanidation ☐ Stamp ☐ Flotation ☐ Jig Plant ☐ Retort ☐
No Mill ☐ Unknown ☐

Neutralizing Host Rock:

Carbonate ☐ Dolomite ☐ Limestone ☐ Marble ☐ Micrite ☐ Sparite ☐

Workings/history:

: Indicate size, number, and type of mine openings, if available.

Years of Operation:

From: To:

Annual Precipitation:

Check one.

Less than 25 centimeters ☐ More than 25 centimeters ☐

5) SPECIALTY DATA:

Check all that apply.

Site in a known or suspected floodplain:

None ☐ Annual - 10 years ☐ 10 - 100 years ☐ 100 - 500 years ☐ Less than once every 500 years ☐

Commodity Groups:

Metals ☐ Coal ☐ Oil and Gas ☐ Uranium or Geothermal ☐
Industrial Minerals ☐ Sand and Gravel ☐ Non-Energy Leasable ☐

Climate:

Humid ☐ Temperate ☐ Semi-Arid ☐ Arid ☐

Threatened and Endangered Plants and Animals:

a) Are any threatened and/or endangered plants and/or animals on or near the site? (Circle one.) **YES** **NO**

b) If present, list type(s):

COMMENTS:

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AML INVENTORY FORM

Part II - Field Data (Side 1)

PAGE ☐ **OF** ☐

SITE NUMBER ☐

DATE ☐

1) FEATURE:

Number: ☐

Fill out one form per feature. Check appropriate box below and supply feature number in space provided.

Adit ☐ Tunnel ☐ Decline ☐ Shaft ☐ Glory Hole ☐ Small Pit or Trench ☐

Large pit ☐ Quarry ☐ Placer mine ☐ Building ☐ Machinery ☐ Solution Mining Well ☐

Mine Dump ☐ Mill Tailings ☐ Sump ☐ Leach pad ☐ Solution Pond ☐ Ore Stockpile ☐

Cistern ☐ Subsidence (linear depressions or holes) ☐ Highwall ☐

Other: ☐

(Some questions below pertain to the selected feature; others pertain to site in general.)

2) CONDITION:

Does the condition of this feature represent a hazard? (Circle one.) **YES** **NO**

(Check the conditions that best describe the physical character of this feature.)

Open to Entry ☐ Partly caved ☐ Concealed ☐ Partly concealed ☐ Not concealed ☐ Collapsed ☐

Partly collapsed ☐ Standing ☐ Empty ☐ Rotten cribbing ☐ Unstable walls ☐ Eroded ☐

Partly eroded ☐ Intact ☐ Confined ☐ Unconfined ☐ Breached ☐ Subsided ☐

Foundation ☐ Prone to wind erosion ☐ Other ☐

3) SIZE OF FEATURE:

Indicate size of feature and specify units (feet or meters).

Length ☐ X Width ☐ X Depth ☐

feet ☐

meters ☐

4) WATER:

The condition of water may indicate the presence of acid mine drainage.

Is water present at the feature? (Circle one.) **YES** **NO**

Is water emitting from or passing through the feature? (Circle one.) **YES** **NO**

Are bodies of water (i.e. rivers, lakes, etc.) found on or near the site? (Circle one.) **YES** **NO**

a) If water is present, how does it occur? (Check all that apply.)

Standing ☐ Filled ☐ Partly filled ☐ Flowing ☐ Intermittent ☐

b) If water is present, take pH and conductivity readings.

Conductivity : ☐ pH: ☐

b) If water is present, observe water bed color. (Check all that apply, or specify other.)

Brown ☐ green ☐ Yellow ☐ Yellow-orange ☐

Orange ☐ Grey-black ☐ Other (specify): ☐

5) PLANTS:

Are plants present on or around the feature? (Circle one.) **YES** **NO**

a) If yes, check one.

Healthy ☐ Stressed ☐ Dead ☐ Other (specify): ☐

6) STAINING:

Stains may indicate spills, oxidation or alteration. Do stains occur on rocks, foundations, or other non-water related features? (Circle one.) **YES** **NO**

a) If stains are present, check appropriate color or specify other.

Yellow-orange ☐ Grey-black ☐ Other (specify): ☐

U.S. Bureau of Mines

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AML INVENTORY FORM

Part II - Field Data (Side 2)

PAGE ☐ **OF** ☐

SITE NUMBER ☐

DATE ☐

7) RADIATION: Did pre-field research indicate this area has produced uranium? (Circle one.) **YES** **NO**

a) If yes, take radiation reading and record: ☐ Counts per second (cps)

8) MACHINERY: Is machinery present? (Circle one.) **YES** **NO**

a) Location of machinery: (Check all that apply.)

Inside building ☐ No building ☐ Outside building ☐ Other (specify): ☐

b) Type of machinery: (Check all that apply or specify other.)

Ball Mill ☐ Flotation cell group ☐ Retort ☐ Stamp mill ☐ Crusher ☐

Rod Mill ☐ Amalgamation equipment ☐ Leach tanks ☐ Arrastre ☐

Vats ☐ Ore bins ☐ Tanks ☐ Thickeners ☐

Others (specify): ☐

9) ANIMALS: Are any animals inhabiting the area? (Circle one.) **YES** **NO**

a) If present, list type and location. ☐

10) HUMAN ACITVITY: Is there any evidence of human activity on the site? (Circle one.) **YES** **NO**

a) If present, specify type and frequency. ☐

11) EXPLOSIVES: Are any explosives or supplies found on the site? (Circle one.) **YES** **NO**

a) If present, list type and location. ☐

12) OTHER : Are any of the following present? (Check all that apply, provide comments as necessary below.)

Acrid odor ☐ Drums ☐ Headframes ☐ Antennae ☐ Tramways ☐

Bags ☐ Scrap metal ☐ Wooden Structures ☐ Trestles ☐ Flumes ☐

Pipe ☐ Overhead wires ☐ Overhead cables ☐ Powerlines ☐ Tram buckets ☐

Poles ☐ Towers ☐ Power Substations ☐ Transformers ☐ Fences ☐

Aviation hazards ☐ Other (specify) ☐

13) PHOTOGRAPH NUMBERS:

14) SKETCH NUMBERS:

COMMENTS: Provide an estimate of the extent and significance of the hazards present and their environmental impact.

U.S. Bureau of Mines

AML INVENTORY FORM

DRAFT

Part III - Supplemental Data (Notes, Sketches, Photographs, etc.)

PAGE ☐ **OF** ☐

SITE NUMBER ☐

DATE ☐

NOTE: Be sure to provide a north arrow and the scale on sketch maps.

The Contaminated Great Lakes Sediments Metals Characterization and Treatment Project is being performed under an Interagency Agreement between the Bureau of Mines and the U.S. Environmental Protection Agency (EPA). Work commenced in April 1990 by the Bureau's Minerals Separations Research Group at the Salt Lake City Research Center (SLRC).

The project has been conducted in cooperation with the Engineering-Technology Work Group in the Assessment and Remediation of Contaminated Sediments (ARCS) Program. It is designed to investigate common mineral processing technologies as removal or remediation alternatives for contaminated sediments.

The ARCS program is a five-year effort authorized by the Water Quality Act of 1987. Under this program, EPA's Great Lakes National Program Office (GLNPO) is studying the removal of toxic pollutants from sediments in the Great Lakes system. The objectives of the ARCS program are to assess the extent of sediment pollution in designated areas of concern and to identify and demonstrate options for the removal and/or treatment of the contaminated sediments. The ARCS program is to be completed in 1992.

In the Characterization and Treatment project, the SLRC has studied sediments received from three sites in the Great Lakes identified as priority areas of concern: Buffalo River, New York, on Lake Erie; Indiana Harbor-Grand Calumet River, Indiana, on Lake Michigan; and Saginaw River, Michigan on Lake Huron. The samples contain both organic and inorganic contamination.

The SLRC program was originally aimed at inorganic heavy metals such as arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, and zinc. On request from EPA, certain organic contaminants are followed when encouraging results are obtained on heavy metals.

Preliminary tests indicated a substantial reduction in the material needing expensive treatment could be achieved by separating contaminants into a small, heavily contaminated concentrate and a larger, clean fraction, based on size classification technology.

Contact

J. P. Allen
Principal Investigator
U.S. Bureau of Mines
Salt Lake Research Center
729 Arapeen Drive
Salt Lake City, Utah 84108
(801) 524-6147

Client

Environmental Protection Agency

Particle Separation Process
PCB and Metals in Sediments

Technology Description

This process is used to separate PCB- and metal-laden sediment particles from clean, coarse-grained material. The sediment washing system, developed by Bergmann USA, uses hydroclones, agitation scrubbers, dense media separators, and screens to separate sediments into different solids streams. Bioremediation is used as a secondary treatment for PCBs in the fine-grained fraction. The process is used to reduce the amount of contaminated material requiring disposal. Preliminary tests under the auspices of EPA and the U.S. Department of Interior, Bureau of Reclamation, indicated the use of hydroclones could reduce the amount of material that requires further treatment or disposal by 80 percent. Forced cold-weather shutdown is a limitation in the system.

Technology Performance

A pilot-scale, on-site demonstration began in October 1991 at the U.S. Army Corps of Engineers, Saginaw Bay Confined Disposal Facility (CDF) in Bay City, Michigan, and was completed in June 1992. The demonstration was part of the Assessment and Remediation of Contaminated Sediments (ARCS) Program authorized by the Water Quality Act of 1987.

Approximately 30 cubic yards of sediments dredged from the Saginaw River was treated each day during the demonstration. Contaminants and grain size was monitored at 23 points in the process.

Remediation Costs

Remediation costs of using mineral processing separations on contaminated sediment will vary depending on the size of the project, its location, the complexity of the flow sheet, and the water content of the sediment. When the processing techniques are applied in the mining industry, the cost is usually no more than a few dollars per cubic yard. Differences in scale, complexity, and effluent treatment requirements may drive remediation costs into the range of $20 to $70 per cubic yard.

Contacts

J. P. Allen
Principal Investigator
U.S. Bureau of Mines
Salt Lake Research Center
729 Arapeen Drive
Salt Lake City, Utah 84108
(801) 524-6147

Clients

Environmental Protection Agency

U.S. Army Corp of Engineers

TECHNOLOGY TRANSFER ANNOUNCEMENT

FROM THE U.S. BUREAU OF MINES *SPRING 1990*

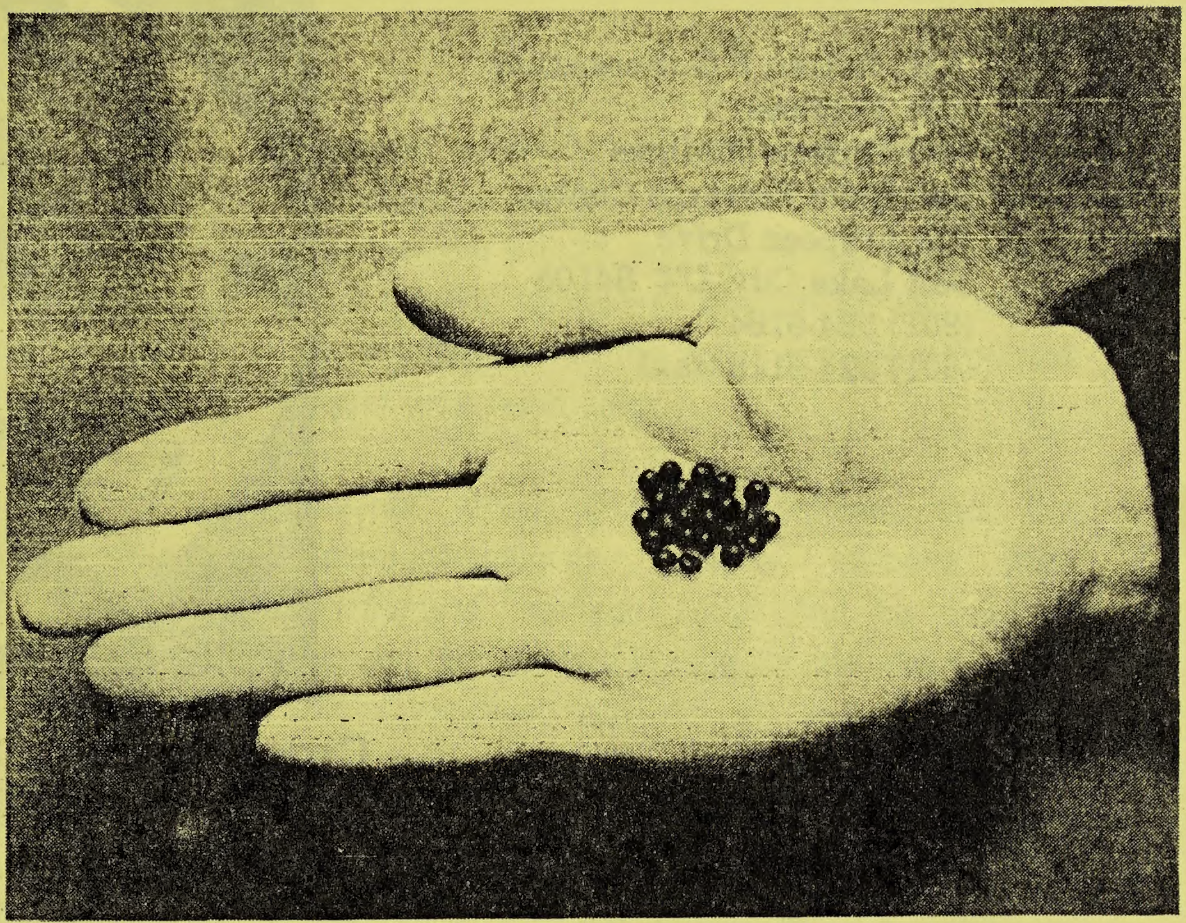
BIO-FIX BEADS Clean Metal Ions from Mining Effluent

--Cheap Method Works On Processing Waste Streams Too

The U.S. Bureau of Mines has developed porous polymeric beads containing immobilized biological materials that readily remove metal ions from mining and mineral processing mine waters. Ions removed include arsenic, cadmium, copper, lead, manganese, mercury, and zinc.

The beads, designated as BIO-FIX beads, are easily fabricated from abundant and inexpensive raw materials. High density polysulfone is dissolved into dimethylfonmamide (DMF), blended with dried dead biomass materials, injected into water, and cured for 16 hours. The beads strongly resist handling and demonstrate long-term stability.

BIO-FIX bead technology was tested in the laboratory using actual mine drainage water. Both active and passive systems were evaluated.



Bio-Fix Beads used to remove metal contaminates from wastewaters.

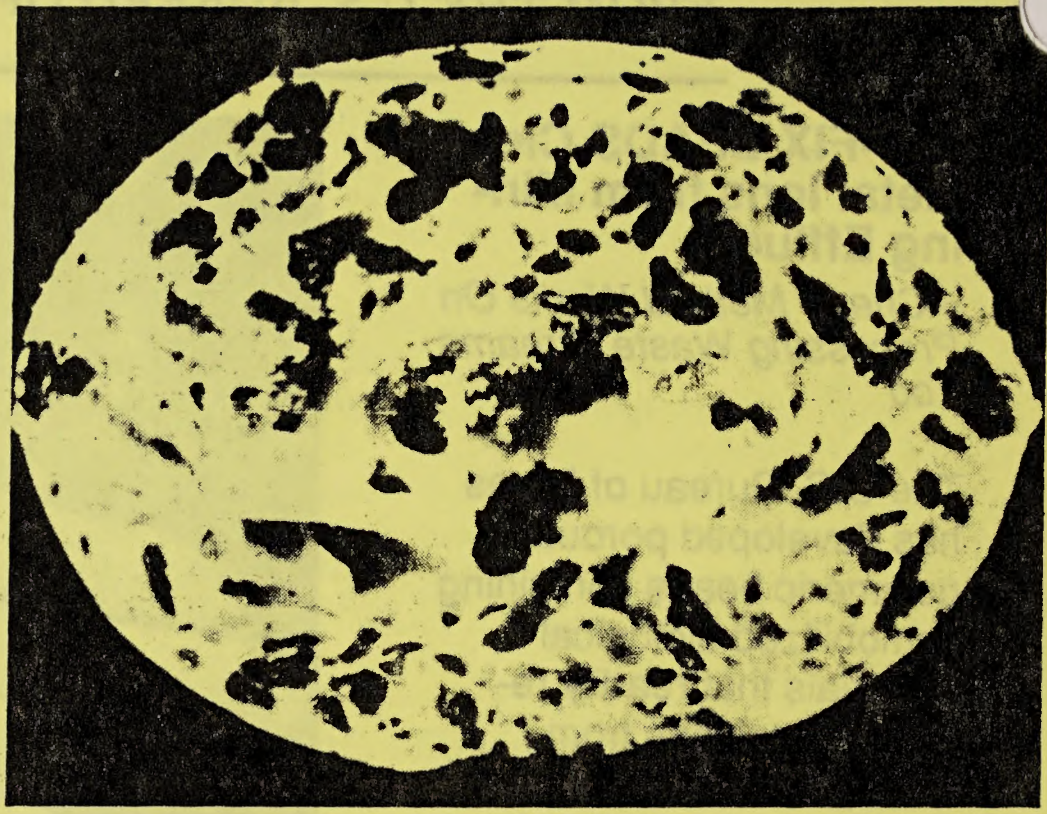
The active system utilized three fixed-bed columns packed with beads. Eighty bed volumes of mine water were processed during each cycle, at a flow rate of 30 bed volumes per hour. The treated effluent consistently met National Drinking Water Standards.

The passive system consisted of beads contained in porous bags that were positioned in a trough. Mine water flowed through the trough by gravity, and the beads extracted essentially all metal ions from the mine water. Again, National Drinking Water Standards were met.

Dilute sulfuric acid effectively stripped the metal values from the BIO-FIX beads in each system. Eluate solutions contained about 200 times as much zinc, cadmium, and other metal ions as the original mine waters. The metal ions were further concentrated by evaporation in order to enable producers to reclaim the metal values. Reclamation avoided the generation of a hazardous sludge, and the problem of disposing of it.

For more information on this
concept, contact

T.H. Jeffers, P.G. Bennett or
C.R. Ferguson
U.S. Bureau of Mines
Salt Lake Research Center
729 Arapeen Drive
Salt Lake City, UT 84108
(801) 524-6164
(801) 524-6119 (fax)



Cross sectional photograph (24X magnification) of a Polysulfone Bead containing Immobilized Biomass.

BACTERIAL SELENIUM REDUCTION IN PRECIOUS METALS SOLUTIONS

Technology Description

The SLRC is also conducting research on bacterial selenium reduction in precious metals solutions. Following cyanide oxidation, the primary contaminant remaining in precious metals solutions is often selenium, present as selenate and selenite. Biological techniques were tested because of the high potential reagent costs associated with chemical selenium reduction. Initial tests were conducted on tailings pond water from an active silver mine containing 280 ppm CN and 4 ppm Se at pH 10.8. Since no selenium-reducing bacteria were found in the tailings pond water, selenium-reducing bacteria isolated from agricultural drainage waters were tested. These bacteria died when added to the untreated tailings pond water due to the toxicity of the high pH and high cyanide concentration, but the bacteria thrived in oxidized tailings pond water at pH 8-9 and <1 ppm CN. Tests conducted in a stirred-tank reactor, rotating biological contactor (RBC), and down-flow submerged columns indicated 85-90 pct of the selenium was reduced from selenate to selenite to elemental selenium and precipitated from solution. Because of the success observed in the treatment of this tailing solution, research is currently underway to determine if these selenium-reducing bacteria could be used to treat solutions from other sources.

Process solutions were collected from three different gold operations and screened for the effectiveness of bacterial selenium reduction. Each solution was inoculated with bacteria and treated in a 3-L stirred tank reactor. The waters contained 0.6, 1.75, and 30 ppm Se after cyanide oxidation. After treatment with the selenium-reducing bacteria, the solutions contained 0.5, 0.25, and 1 ppm Se, respectively. The solution containing 30 ppm Se was treated in two stages with the solids removed from the liquid after each stage.

Overall, these test data indicate that the selenium-reducing bacteria isolated from agricultural drainage water can be used to reduce a high percentage of the selenium in other process solutions as well. However, operating parameters would have to be optimized for each water source. With all the waters tested, further treatment would be required to meet the drinking water standard for selenium of 0.01 ppm. Bacterial selenium reduction is currently being investigated for application during closure of heap and dump leaches at several precious metal operations.

Remediation Costs

Cost information is not available.

Contact

Paulette Altringer
Group Supervisor
U.S. Bureau of Mines
Salt Lake City Research Center
729 Arapeen Drive
Salt Lake City, UT 84108-1283
801/584-4152

Biological Degradation of Cyanide

Decommissioning of Precious Metals Heap Leaching Facilities

Technology Description

This bacterial treatment system provides alternative rinsing technology for decommissioning precious metals heap leach facilities. This alternative increases the rate of cyanide degradation in heaps by activating natural populations of cyanide-oxidizing bacteria indigenous to the site and/or introducing additional populations of natural bacteria with known cyanide-degrading capabilities.

The bacteria-enhanced process increases the rate of cyanide rinsing from the heaps and enables complete water recycling. This has three major advantages: it eliminates the need for toxic or corrosive chemicals to destroy the cyanide in process solutions; it diminishes the amount of fresh water needed for cyanide rinsing; and it eliminates the water balance problem caused by the large volumes of contaminated wastewater generated during conventional rinsing that must be evaporated. Ideally, the bacteria-enhanced rinsing will completely and permanently destroy the cyanide in the process solutions as well as in the heaps.

To implement this technology, cyanide in the process water will be bacterially oxidized as it is pumped through the activated carbon columns in the gold recovery plant and the collection pond. Treated water, containing cyanide-degrading bacteria, is then used to rinse and degrade cyanide in the heaps. If the bacteria present in the rinse water are not sufficient, nutrients and/or known cyanide-oxidizing bacteria will be added to the heaps.

Incorporation of biological cyanide oxidation into precious metals heap decommissioning procedures will decrease the time required to meet final closure limits, decrease water requirements during the rinsing process, and eliminate the need for toxic or corrosive chemicals for cyanide degradation.

Technology Performance

Commercial application of the process is designed to use the carbon adsorption columns in the gold recovery plant, the collection pond, or the heap as bioreactors. Laboratory tests were conducted to simulate these conditions. Bacteria effectively oxidized cyanide to varying degrees in each instance. For example, in tests designed to simulate the gold recovery plant, bacteria oxidized cyanide from between 50 and 170 ppm WAD CN in the feed solution to 0.1 ppm WAD CN in the treated water in <1 hour.

Field demonstration of the biological cyanide oxidation system is scheduled to occur during decommissioning of a Nevada heap leach operation in the Summer of 1992.

Remediation Costs

Cost information is not available.

Contact

Paulette Altringer
Group Supervisor
U.S. Bureau of Mines
Salt Lake Research Center
729 Arapeen Drive
Salt Lake City, Utah 84108-1283
(801) 524-6152

Client

USMX - Denver

MICROBIAL AND CHEMICAL ARSENIC REMOVAL FROM WASTES

OBJECTIVE

Identify arsenic-contaminated wastes associated with mining and milling industries and develop microbial technology to control such contamination. This project was initiated in October 1990 and the data is preliminary in nature. Several bacteria have been cultured and are being isolated and identified as they show promise for arsenic removal. Tests are being conducted in flasks and columns.

PROBLEM OVERVIEW

In October of 1986, the President of the United States signed into law the Superfund Amendments and Reauthorization Act of 1986 (SARA). This law provided new standards for hazardous waste management in which "remedial actions ... which permanently and significantly reduce the volume, toxicity, or mobility of the hazardous substance... are to be preferred." In many cases treatment technology to meet stringent discharge requirements does not exist. Even implementing best available technology often results in only partial compliance. Arsenic is an excellent example. Arsenic is listed as a major contaminant at about 150 sites on the National Priority List (NPL) and is probably the most common inorganic hazardous waste contaminant in the western part of our country. The key to treating both solid wastes and associated seepage waters is essentially complete removal of arsenic. Arsenic is one of the most difficult metals to remove from solution, especially to the low levels required to meet current drinking water standards.

RESPONSE

The Bureau of Mines' research program at Salt Lake City is developing biological and chemical technology for treating arsenic-contaminated wastes.

The most-commonly used chemical technology for treating contaminated water is precipitation, usually with iron, but this requires copious amounts of chemicals and produces voluminous amounts of waste. As an alternative technique, researchers are isolating bacteria that thrive in arsenic waste in hopes of utilizing naturally occurring microorganisms that remove arsenic from waste.

PROGRESS

Research has been initiated to culture and test bacteria that precipitate arsenic from contaminated waters and leach arsenic from contaminated solids. While many bacteria will live in arsenic-contaminated waters, few will reduce the arsenic to an insoluble form that can be removed from solution. One consortium of bacteria, cultured from ground water, is currently reducing arsenate to arsenite and then to a solid precipitate in laboratory prepared solutions. These bacteria will be further tested in actual surface and ground waters contaminated with arsenic. Another strain of bacteria, known as Thiobacillus ferrooxidans, is being tested to leach arsenic from contaminated solid waste.

Remediation Costs

Cost information is not available.

Contact

Paulette Altringer
Group Supervisor
U.S. Bureau of Mines
Salt Lake City Research Center
729 Arapeen Drive
Salt Lake City, UT 84108-1283
801/584-4152

United States Department of Agriculture

Forest Service

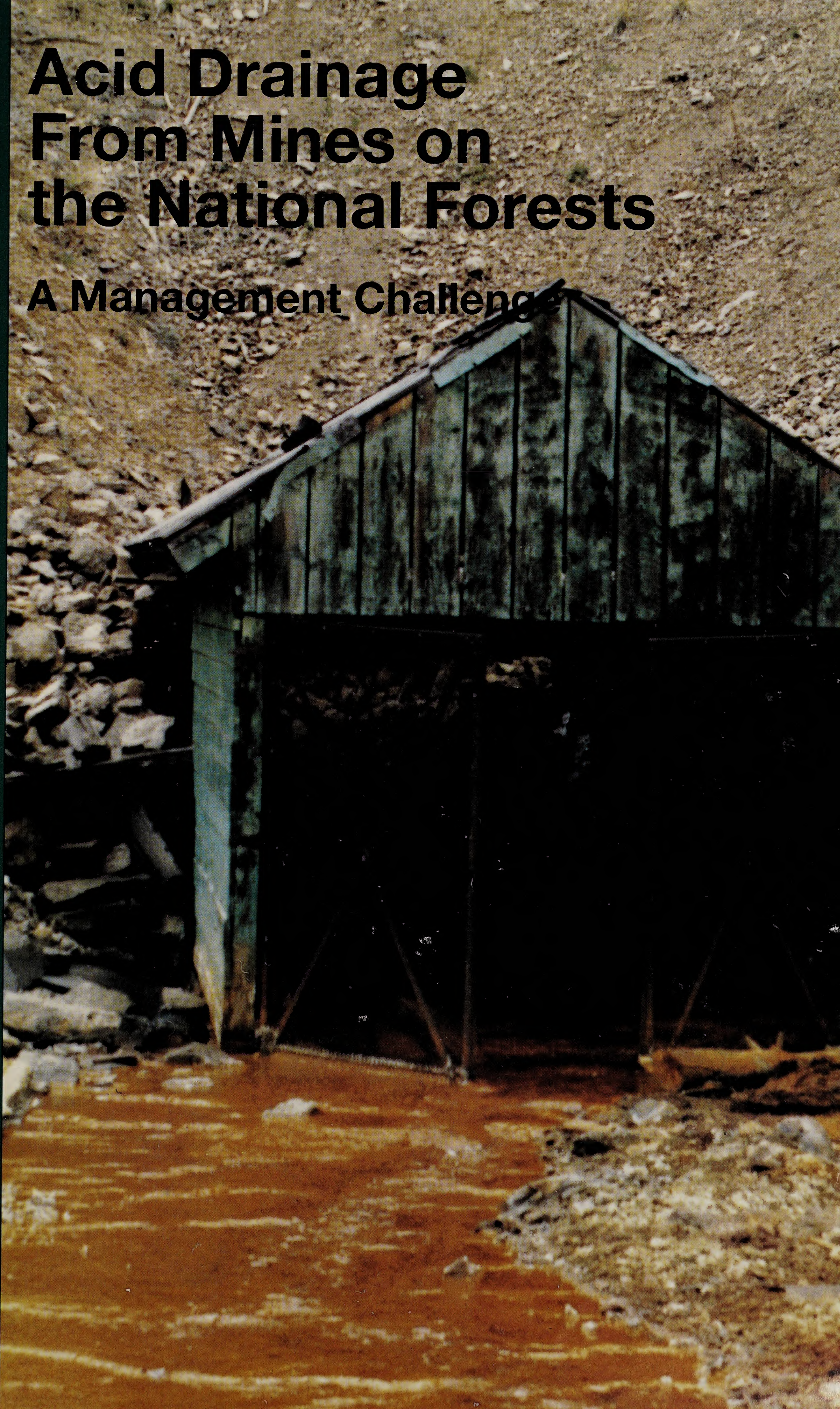
In Cooperation with the U.S. Department of the Interior's Bureau of Mines

Program Aid 1505

March 1993

Acid Drainage From Mines on the National Forests

A Management Challenge



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- Program Monitoring and Technology Transfer

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On the Front Cover

Old mine adit on the Rio Grande National Forest in Colorado. Although partially collapsed, this adit still drains a historic lead, copper, and zinc mine. High acidity and high metal content have severely affected aquatic lifeforms below the mine.

All photos USDA FS/WO–M&GM

Cooperative Research Program *–An Overview*

> *"The Forest Service has identified acid drainage from mine sites as the most difficult and costly reclamation problem it faces with western metalliferous mining operations . . . with some significant environmental problems dating as far back as the late 1800's."*

When the cooperative research plan on acid drainage from mine sites was signed in April 1991 by the Bureau of Mines and the Forest Service, its mandate was clear—to provide and apply technology to help manage national forests and grasslands affected by acid drainage. The plan represents a long-term cooperative research program focusing on National Forest System lands in the Western United States being carried out using the Research, Development, and Application (RD&A) model. It is a comprehensive program with practical goals—to provide and make use of needed information.

Under the program:

- The Bureau of Mines provides information on the prediction, control, and treatment of acid drainage from mine sites.
- The Forest Service, the mining industry, and others provide research sites and use the information.
- The Forest Service monitors its effectiveness.

This report highlights program contributions to be achieved over time. It also summarizes contributions of the program to date and describes how the program functions. The current effort is a long-term one, using available resources. Additional resources specifically designated to this cooperative effort would result in accomplishing the work in a more timely fashion.

Of course, the true effectiveness of the acid drainage cooperative research program will not be known for some years. Applying the results of new research and development is not accomplished quickly—it takes time. Fortunately, application of this new information being provided by the Bureau of Mines will be a continuing part of Forest Service programs.

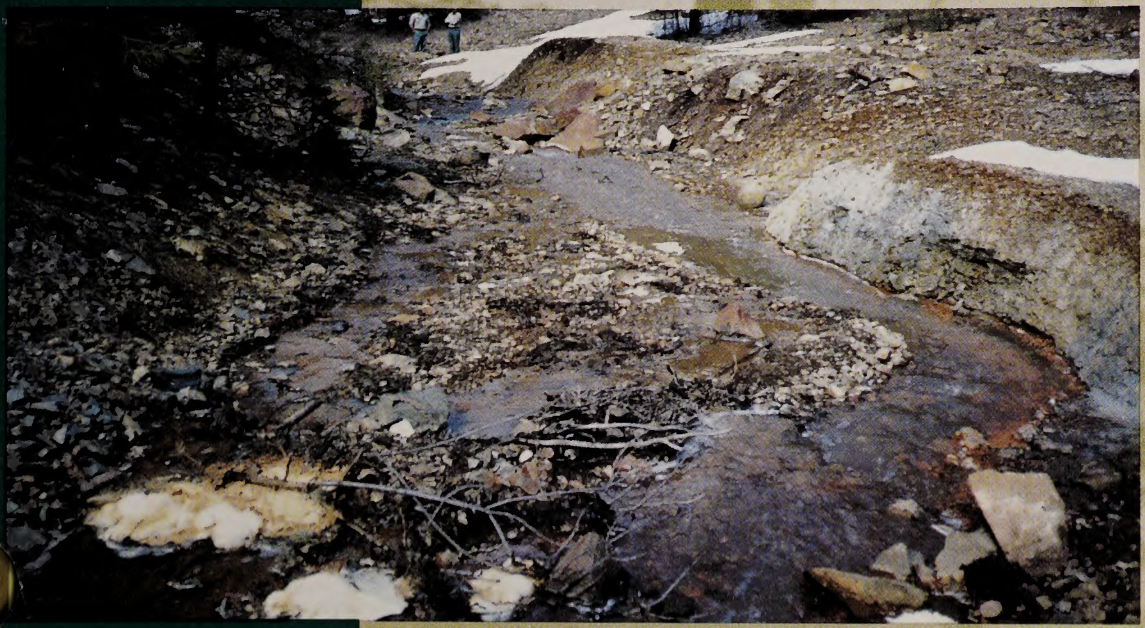

Figure 1
Mine tailings producing acid drainage on the Prescott National Forest in Arizona. This gold, lead, and zinc was active in the 1890's.

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The U.S. Department of Agriculture's Forest Service and the U.S. Department of the Interior's Bureau of Mines each has unique responsibilities in the management of mineral resources in the United States. Generally, the overall responsibility for managing federally owned minerals belongs to the Bureau of Land Management. Other Department of the Interior agencies have minerals responsibilities as well.

In part, the Forest Service is charged with administration and management of National Forest System lands, including land and resource management planning. This responsibility encompasses the mining and extraction of mineral resources, the approval of mining and reclamation plans that protect the environment, particularly surface resources, and the research necessary to protect these resources. The Bureau of Mines has responsibility to ensure that the United States has a dependable and secure supply of domestic minerals, to conduct investigations and research for this purpose, and to protect the environment and minimize damage due to mining and mineral processing activities.

In June 1990, the two agencies entered into a Memorandum of Understanding to enable them to develop and carry out a comprehensive research program to solve problems and demonstrate solutions to acid drainage problems on National Forest System lands. It is an important program, in that solutions to problems such as these are necessary for the extraction of mineral resources in an environmentally sensitive manner. In effect, it influences the degree to which minerals necessary for the economic viability of the Nation are available on these lands.

> *"The Forest Service and Bureau of Mines have entered into a Memorandum of Understanding to enable them to develop and carry out a comprehensive research program to solve . . . acid drainage problems."*

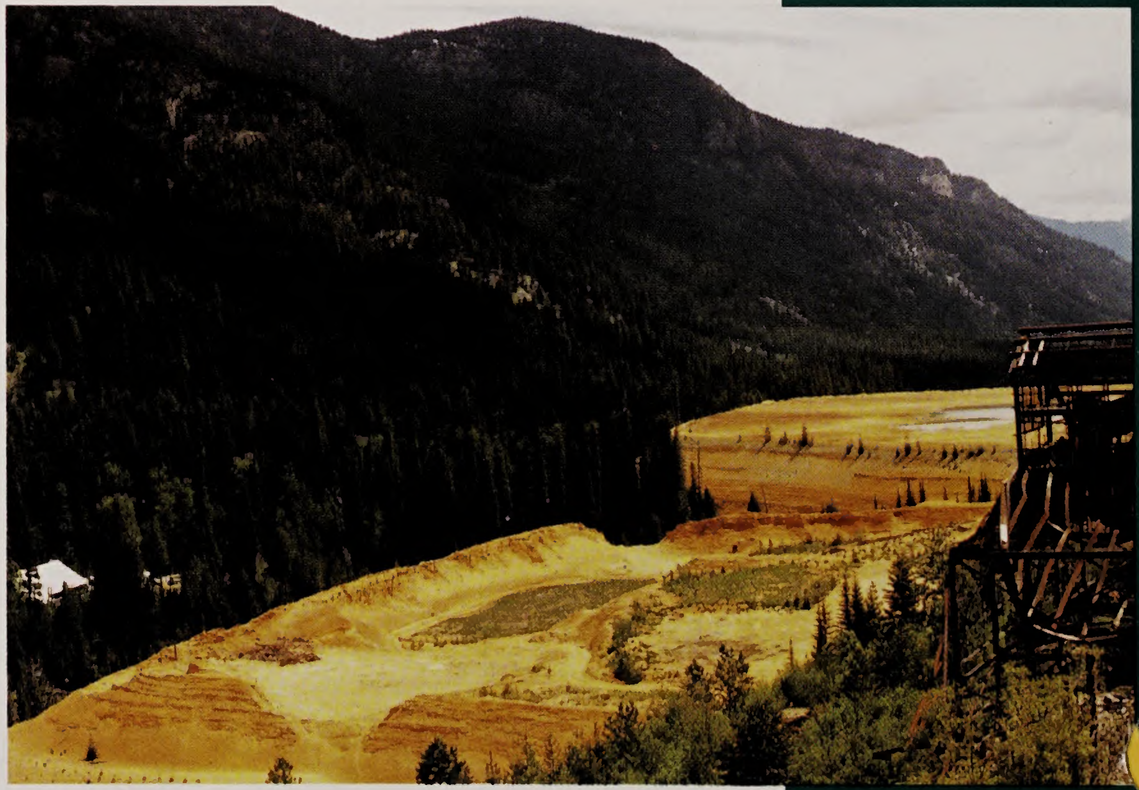


Figure 2
Acid is generated from these abandoned mill tailings on the Wenatchee National Forest in Washington. The primary commodity was copper. The color of the tailings results from precipitated iron.

The Forest Service has identified acid drainage from mine sites as the most difficult and costly reclamation problem it faces with western metalliferous mining operations. Acid drainage persists at many active and abandoned mine sites, with some significant environmental problems dating as far back as the late 1800's. There are also concerns that current and future mining operations may generate acid drainage for years or decades after the mines cease operation. Unfortunately, major technical uncertainties are associated with the prediction of acid drainage potential at the time of mine plan approval as well as with mitigation or treatment techniques for post-mining use.

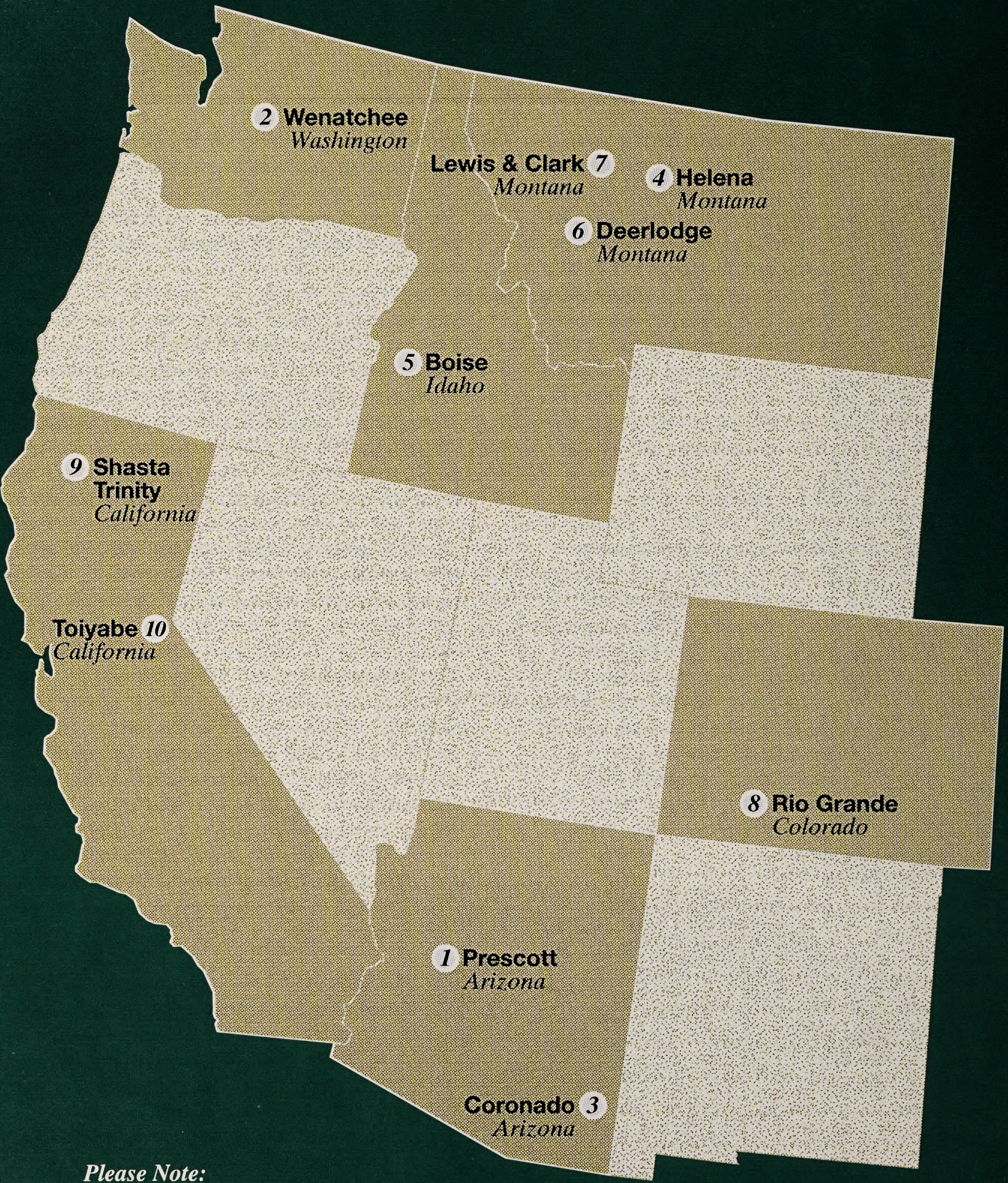
Over 1,500 western mining sites with significant acid drainage problems have been identified on National Forest System lands. Many of these sites in remote locations that are not accessible the year around often represent small, but ecologically damaging flows. Such sites require either permanent control measures to prevent or mitigate acid formation, or low-cost, passive treatment technology to neutralize and detoxify the waters. The problems of acid drainage from the sulfide-bearing rock present at many western metal mines are exacerbated by contamination that occurs when acid waters contact exposed mineral zones and dissolve heavy metals. Many of these metals are toxic to aquatic and terrestrial life, if the concentrations are high enough.

Forest Service land managers, who face increasingly complex and controversial decisions regarding mineral development, need new research information. One major problem affecting the future of metal mining in the West is the absence of technology to predict the potential of new mining ventures to generate acid drainage. State and Federal permitting and regulatory agencies need information on the acid-forming potential of ore deposits in order to analyze the impacts of new mining operations and provide for the development of necessary environmental controls. Gold and other precious metal operations, which have experienced a 30- to 35-percent growth in domestic production in each of the last 5 years, are expected to continue. Without additional research information, it is almost certain that a significant percentage of existing and new mining ventures will experience unexpected acid drainage situations. These situations could result in expensive and difficult remedial actions to prevent adverse environmental impacts, primarily to surface and ground waters, due to metal-contaminated drainage.

The fact that acid drainage has been a persistent problem for more than 100 years is indicative of one of the major difficulties in dealing with it—that there are currently no widely applicable technologies to mitigate or stop a fully developed acid drainage situation. Only stopgap prescriptions are available and at considerable cost. On the other hand, the application of State and Federal regulatory controls on some modern mines has, in some instances, been able to limit the development of acid mine drainage and consequently reduce the long-term environmental effects. However, regulatory controls do not always work. In the case of old, abandoned mines it is too late for regulatory controls. New technologies are needed to effectively deal with these problems.

Currently, reliable data on the total number of mines producing acid drainage and on the number of miles of streams affected by acid and metal drainage are not available for the Western United States. However, various estimates have placed the number of these mines in the range of 20,000-50,000, seriously affecting 5,000-10,000 miles of streams. The cumulative effect of these mines, whatever their actual number, is significant.

The basis for the production of acid drainage is well understood. Pyrite and other sulfide minerals are exposed to air and water in the mining process. Air and water oxidize the sulfide minerals, releasing sulfuric acid and sulfates. This process is catalyzed by iron-oxidizing bacteria and permits a host of site-specific secondary reactions, principally ion exchange and acid-induced metal dissolution. The metals that may be involved in this process cover the range of heavy metals: arsenic, cadmium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, and zinc. Once the chemical reactions are fully realized, the discharge of acid and metal ions is known to persist



Please Note:

States in solid color are the ones represented by photos in this publication. However, acid drainage from metal mines is a problem throughout the West.

A sampling of national forests having acid drainage problems. Numbers refer to figure numbers in this publication.

in some cases for hundreds of years and should be considered a long-term source of contamination. Although this process does occur naturally, it is the volume of drainage from mine sites that is problematic.

The makeup of acid drainage varies from mine to mine and from location to location. Classic acid drainage is composed of acid, precipitated iron compounds, sulfate ions, and dissolved metals. It is the metals, far more than the acidity, that cause the environmental damage. The type of metals in acid mine drainage is controlled by the mineralogy of the ore body; lead and zinc mines may produce metal migrations of lead and zinc. Unexpectedly, gold mines may produce flows containing arsenic. Once the acidity and metal ions migrate into the soils, they are usually unable to support the normal complement of vegetation and soil fauna and flora. These biological components of the soil are inhibited by the dissolved metals in the soil water solution. Bare, unvegetated soils are eroded by the weather elements, and streams are physically contaminated with large volumes of metal-bearing sediments coming off the acidified upland areas of the mines. Extant groundwater aquifers may also be contaminated by the dissolved metals.

When acid and metal drainage enters streams, the fish and other stream organisms are often depleted in a relatively short period of time. Copper ions are especially lethal to fish, but not to mammals. In a coldwater fishery, in softwater conditions, a copper concentration of as little as one part per million may be lethal to trout. Streamside vegetation is affected by a change in species composition and exhibits a general loss of vigor. However, some lower quality streamside vegetation is usually retained.

To briefly summarize, flows of acid drainage often create large, toxic, metal-bearing sediment loads in stream channels. The channels may be brightly colored—red, purple, and orange—by precipitates of iron and other metal compounds. The waters are somewhat acidified, but the metal constituents may increase drastically. Fish and other organisms in the system are lost in the waters most affected as a result of the metal contamination. Streamside vegetation is often changed as to species composition and loss of vigor. The most seriously affected streams are considered to be "dead." Ground water may also be contaminated with metal ions.

A Model of Cooperation

"Without additional research . . . it is almost certain that a significant percentage of existing and new mining ventures will experience unexpected acid drainage situations that could result in expensive and difficult remedial actions . . . ."

The current gold boom in the Intermountain West began in the mid 1980's. It was made possible by a combination of high precious metals prices; discovery of large, low-grade, disseminated ore deposits; and new extraction technology. By the close of the decade, the Forest Service and some segments of the mining industry had recognized the need for better research information to deal with the likelihood of acid drainage. Acid drainage research and development efforts were generally not well coordinated with the needs of the national forests, and adequate planning for this type of focus was often lacking. For this reason, effective June 6, 1990, a Memorandum of Understanding was signed by the Bureau of Mines and the Forest Service in which the two agencies mutually agree to cooperate in addressing the significant national problem posed by acid drainage from mine sites in the Western States. The agreement does not include funding considerations.

A joint agency working group established by the agreement has identified four priority areas that must be addressed to develop effective solutions to acid drainage problems in the West. Together, these areas make up the cooperative research program. They relate to (1) predictive techniques and methodologies to assess the potential of new mining ventures to generate acid waters; (2) control technologies to prevent or minimize acid drainage; (3) treatment technologies to mitigate existing acid drainage problems; and (4) technology transfer and program monitoring to assess the effectiveness of technologies in the above three areas and transfer the information to the mining industry and government agencies.

Under the direction of the national offices of the Forest Service and the Bureau of Mines, the joint agency working group is responsible for program planning, setting research priorities, identifying field study and demonstration sites, and information exchange.

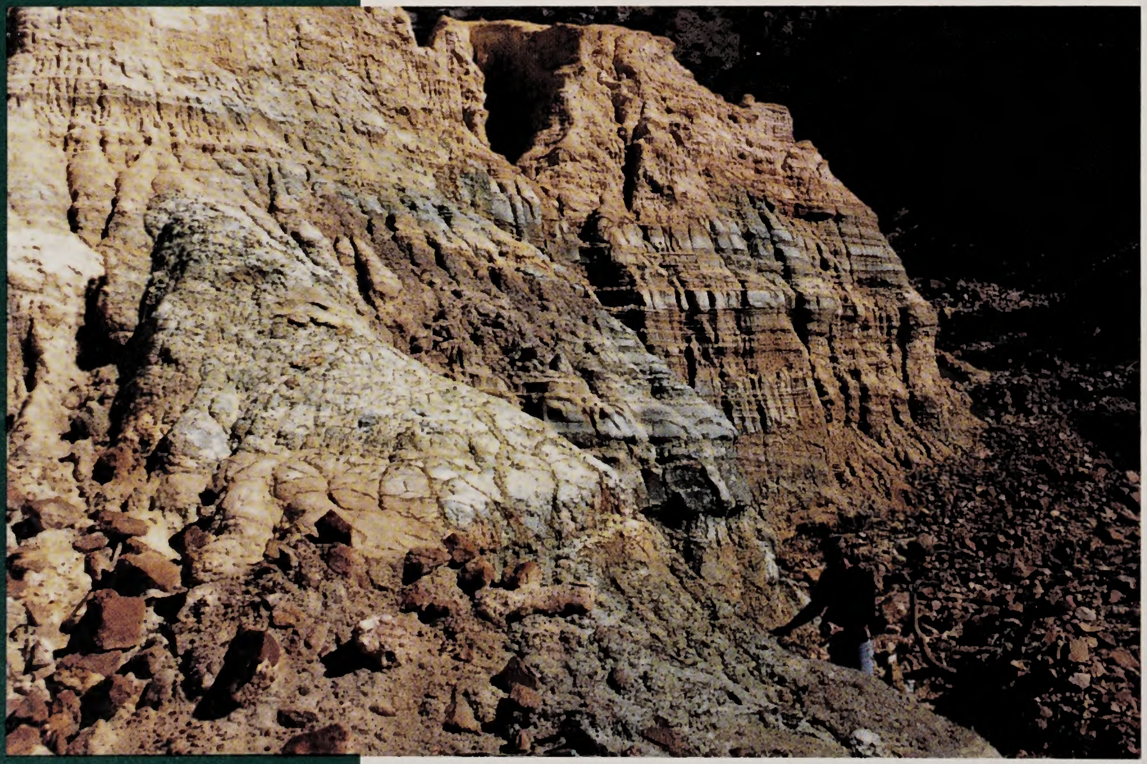


Figure 3
Eroded mine and mill tailings generate acid on the Coronado National Forest in Arizona. The operation produced copper, silver, gold, and other metals.

The cooperative **research** program is a shared effort between the Bureau of Mines and the Forest Service. Basic research information forms the technical foundation of any such program. Although much new technology needs to be generated for the Western United States, some technology is already available in the East upon which to build. Much attention has been directed at acid problems associated with eastern coal mines. In fact, the Bureau of Mines has had an active research program to address acid drainage from eastern coal mines for more than 20 years and has produced a number of successful reclamation, mitigation, treatment, and pre-mine prediction technologies.

Development involves molding existing knowledge and technology into a form that can be used in specific ways. In this case, development efforts will utilize the knowledge base on treatment of acid drainage from eastern coal mines and the extensive expertise of the Bureau of Mines in mining and processing of oresfrom western metal mines. Research and development in this RD&A model is being accomplished by the Bureau of Mines with Forest Service support.

Effective **application** of the cooperative model involves successful technology transfer. Unfortunately, considerably greater emphasis is frequently placed on generating information than on transferring it to users and getting it applied. As a result, a great disparity can exist between the amount of information available and the amount used. In this model, technology transfer is being emphasized and includes usage of the information on the ground. Monitoring to determine the effectiveness of new technologies is considered an integral part of application. The Forest Service, because it administers the land and regulates mining activity, has responsibility for application of research and development information with Bureau of Mines support.

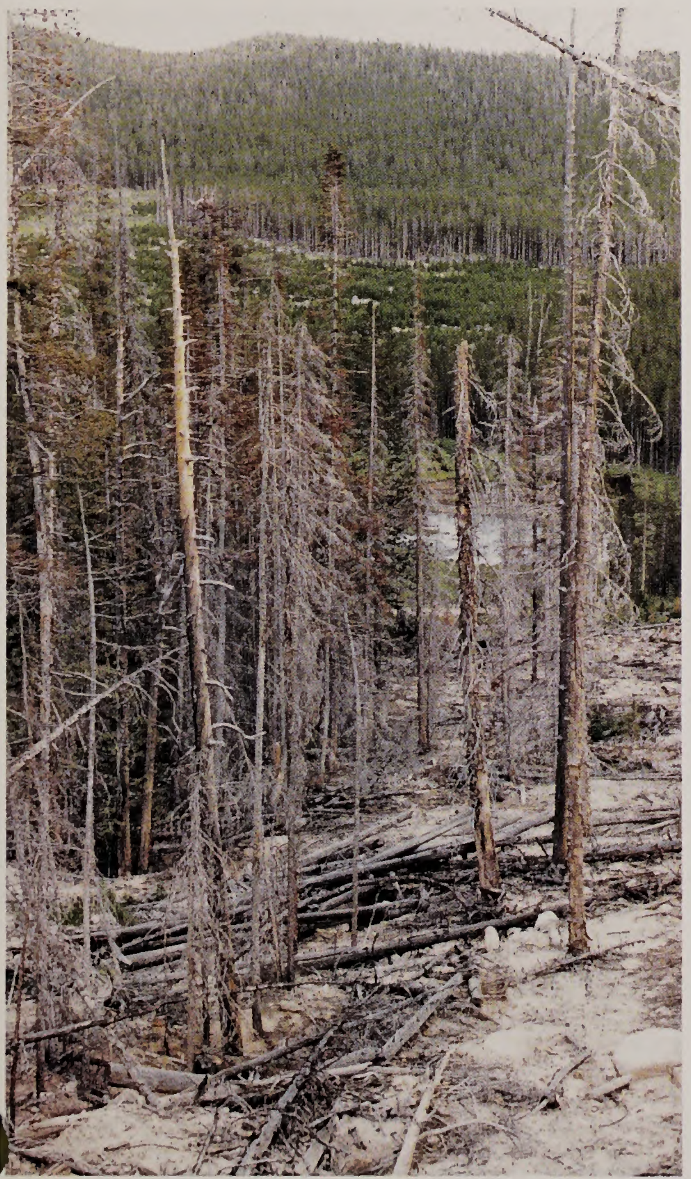


Figure 4
Trees killed by heavy-metal-contaminated acid drainage seeping from sulphide-bearing waste rock on the Helena National Forest in Montana. The mineral commodity was gold.

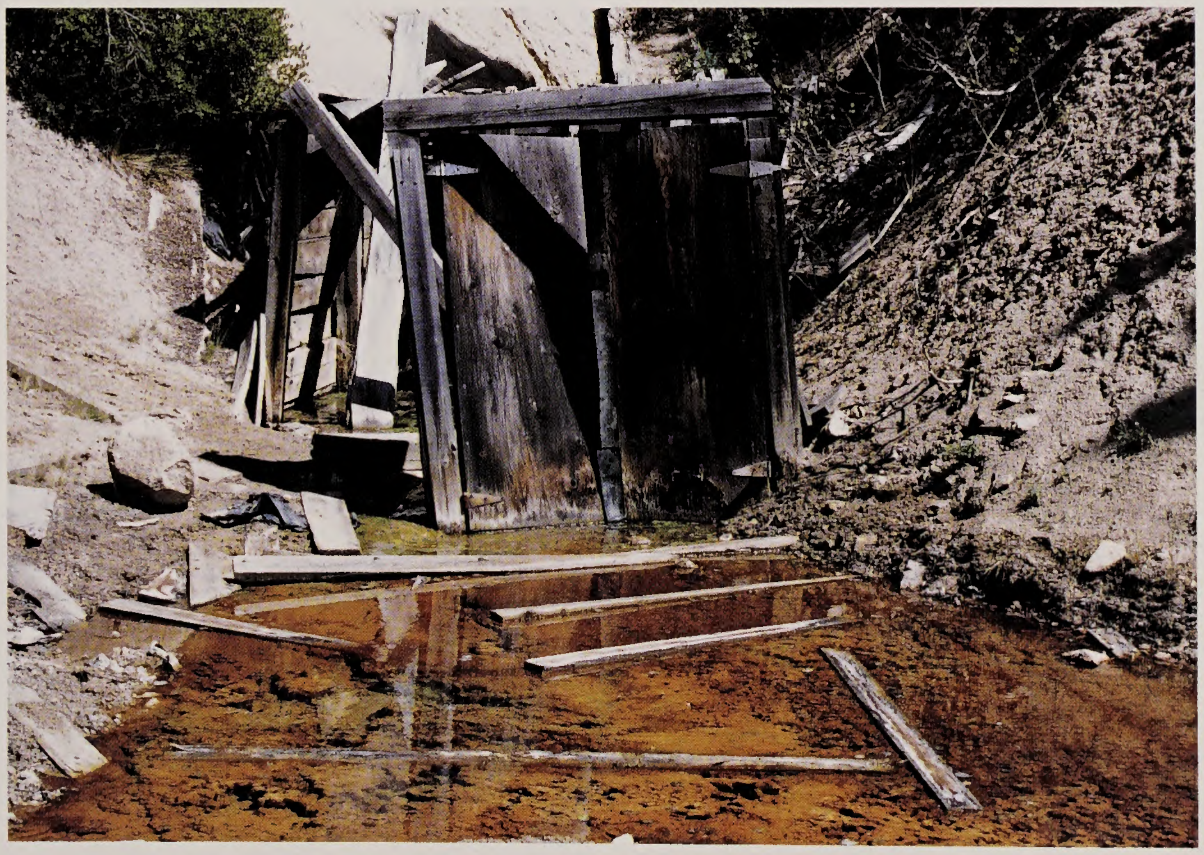


Figure 5
Acid rock drainage seeps from an abandoned mine adit on the Boise National Forest in Idaho. This water has unusually high concentrations of arsenic.

The Solution

The real value of a cooperative research program depends on its ability to accomplish specific objectives in a given period of time. In addition, the speed at which a program functions is directly related to the resources allocated to it. Therefore, ideally, information and technologies to solve acid drainage problems from mines on National Forest System lands should be generated quickly, followed by a period during which agencies and the mining industry focus on implementing the solutions. The RD&A approach allows for concentration on high-pay-off projects that would otherwise not be accomplished. Following is an explanation of the four priority research areas:

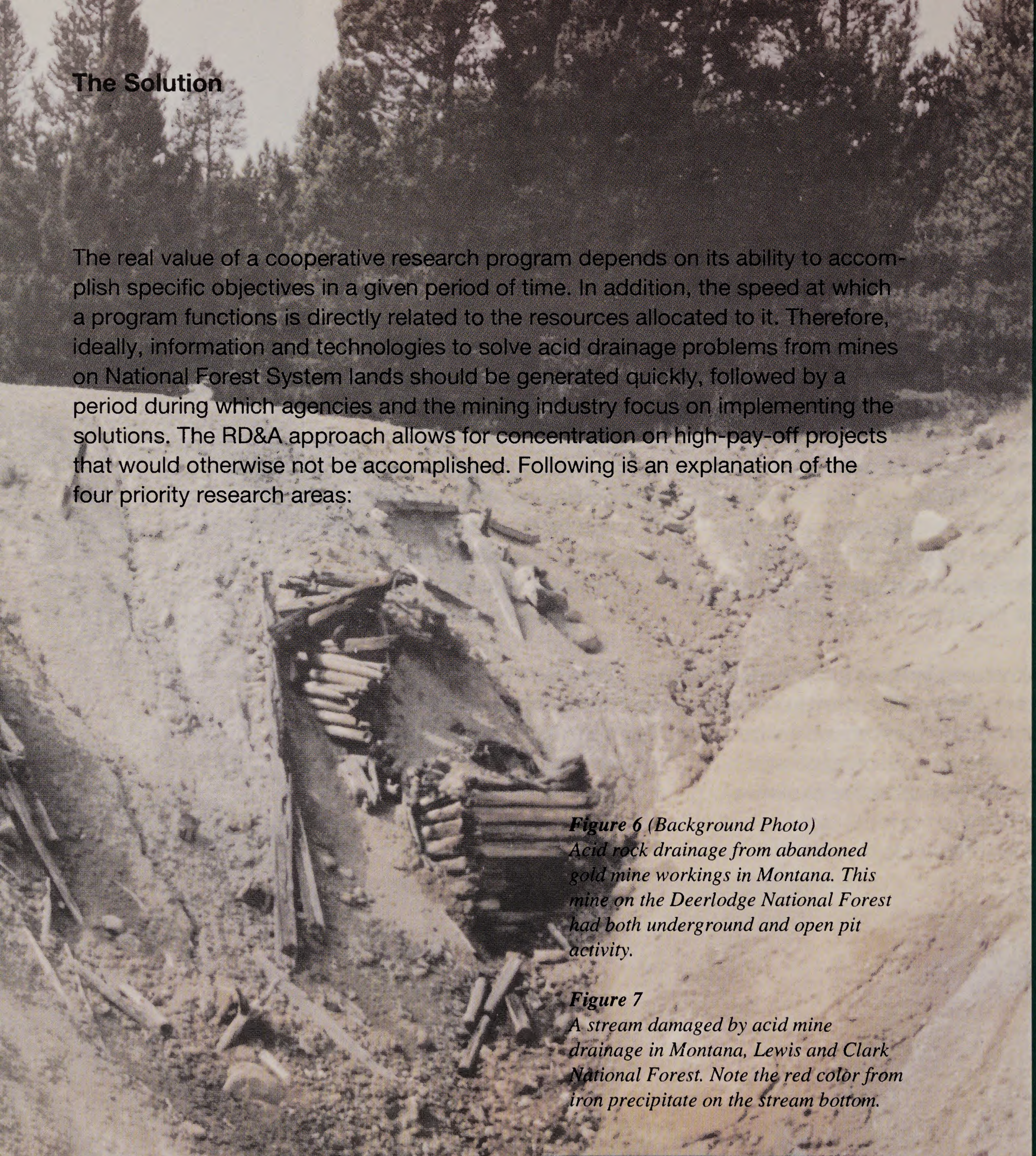
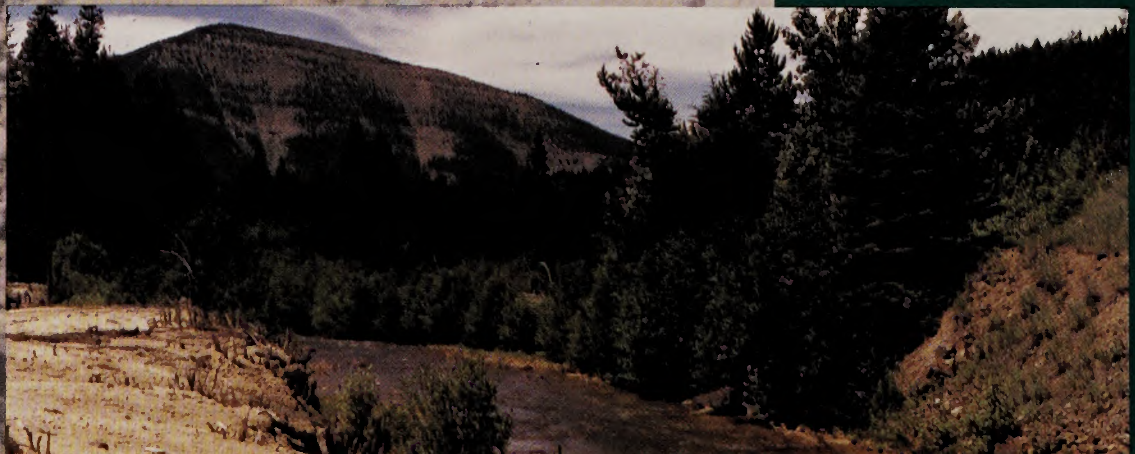


Figure 6 *(Background Photo)*
Acid rock drainage from abandoned gold mine workings in Montana. This mine on the Deerlodge National Forest had both underground and open pit activity.

Figure 7
A stream damaged by acid mine drainage in Montana, Lewis and Clark National Forest. Note the red color from iron precipitate on the stream bottom.



> *". . . development of effective techniques and methods for predicting the potential of new mining ventures to form acid drainage. . . . would allow the Forest Service, other land management agencies, and industry to avoid repeating the mining mistakes of the past . . . ."*

Acid Drainage Prediction

Scope: The Forest Service and the Bureau of Mines concur that the development of effective techniques and methods for predicting the potential of new mining ventures to form acid drainage is one of the highest priority efforts of cooperative research. In essence, predictive technologies would allow the Forest Service, other land management agencies, and industry to avoid repeating the mining mistakes of the past that have led to acid drainage problems. An accurate assessment of the potential for acid drainage formation using information obtained during exploratory drilling, for example, could be used in the permitting process. In addition, the assessment would allow industry to design mine and waste management plans to prevent or mitigate adverse environmental impacts from acid drainage.

Objective: Within 5 years, develop quantitative models, techniques, and methods for the prediction of acid drainage from samples obtained from exploratory drilling programs.

Control Technologies for Acid Drainage

Scope: There is a need for more effective technologies to control acid drainage at both abandoned and operating mine sites. Control aims to prevent acid drainage formation by inhibiting the weathering processes, for example, by preventing water or oxygen contact with mine wastes or mine workings. This technology is applicable to past sites and to all new operations through the development of mine and waste management plans.

Objective: Develop and demonstrate a suite of economical techniques that limit effluent volumes or heavy-metals concentrations from mines and waste rock (nonpoint sources of pollution). These include underground mine workings and pits, coarse waste rock, and fine fractions of mill wastes.

Treatment Technology for Acid Drainage

Scope: Cost-effective technology is needed to correct acid drainage from past operations. The development of a low-maintenance or passive treatment process may be the only cost-effective solution for many national forest sites because of their location, low-volume discharge, or extensive and diffuse underground contamination source. Research should focus on developing low-cost chemical and biochemical systems for small-volume discharges that can operate with minimum maintenance.

Objective: The 5-year objective is to develop a passive, low-maintenance system or systems for treating low-volume drainage from mine adits (point sources of pollution). Treatment may involve combined passive systems, which ideally would produce dense and environmentally stable sludges and have the potential for metal recovery to limit disposal costs.

Program Monitoring and Technology Transfer

Scope: The need to determine the effectiveness of new acid drainage technologies has resulted in a commitment on the part of the Forest Service and the Bureau of Mines to carry out long-term monitoring in the above three research areas. In addition, improved knowledge and technologies to predict, control, and treat acid mine drainage will require aggressive technology transfer, training, and information sharing efforts.

Objectives: Develop and carry out long-term monitoring and evaluation plans consistent with the level of new methods and techniques. Enhance the awareness of acid drainage problems and solutions with the mining industry and State and Federal land management and regulatory agencies.

Benefits

". . . application of this new information being provided by the Bureau of Mines will be a continuing part of Forest Service programs."

The benefits of an effective RD&A program include:

- The ability to predict the potential for acid drainage from mine sites will enable land managers to make informed decisions regarding the exploitation of metallic mineral resources on public lands.
- Predicting the likelihood of acid drainage prior to mining will enable industry to design effective control and mitigation measures into the mining operation.
- The economic viability of the mine can be better assessed. This will reduce premature and ineffective closure due to unexpected environmental control costs.
- A better design for final mine closure can be prepared. Post-mining site monitoring will be reduced, and the time for monitoring will be shortened.
- New techniques will prevent or reduce acid discharges from metal mines and processing wastes. Elimination of these discharges will preclude or reduce acid and heavy metal pollution of receiving streams and ground waters.
- Improved drinking water supplies and restoration of acquatic habitat will result. There will be an elimination of visual pollution of streams due to precipitation of iron compounds.
- Reduced costs for waste water treatment and correcting other damage to the environment.

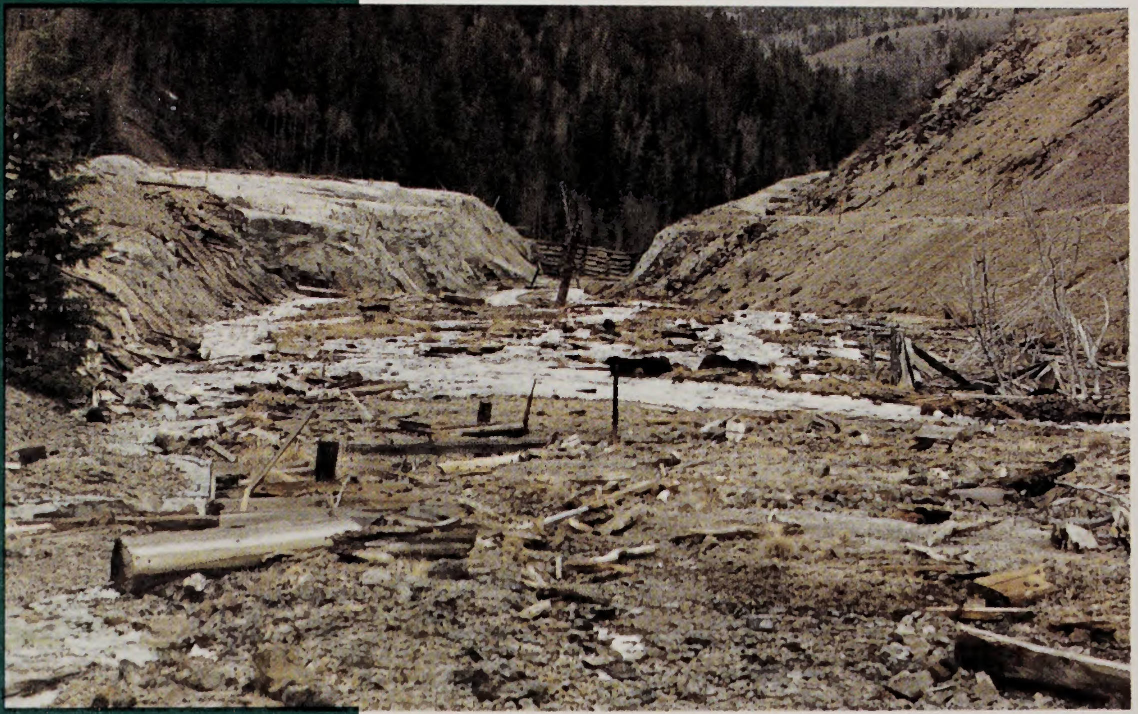


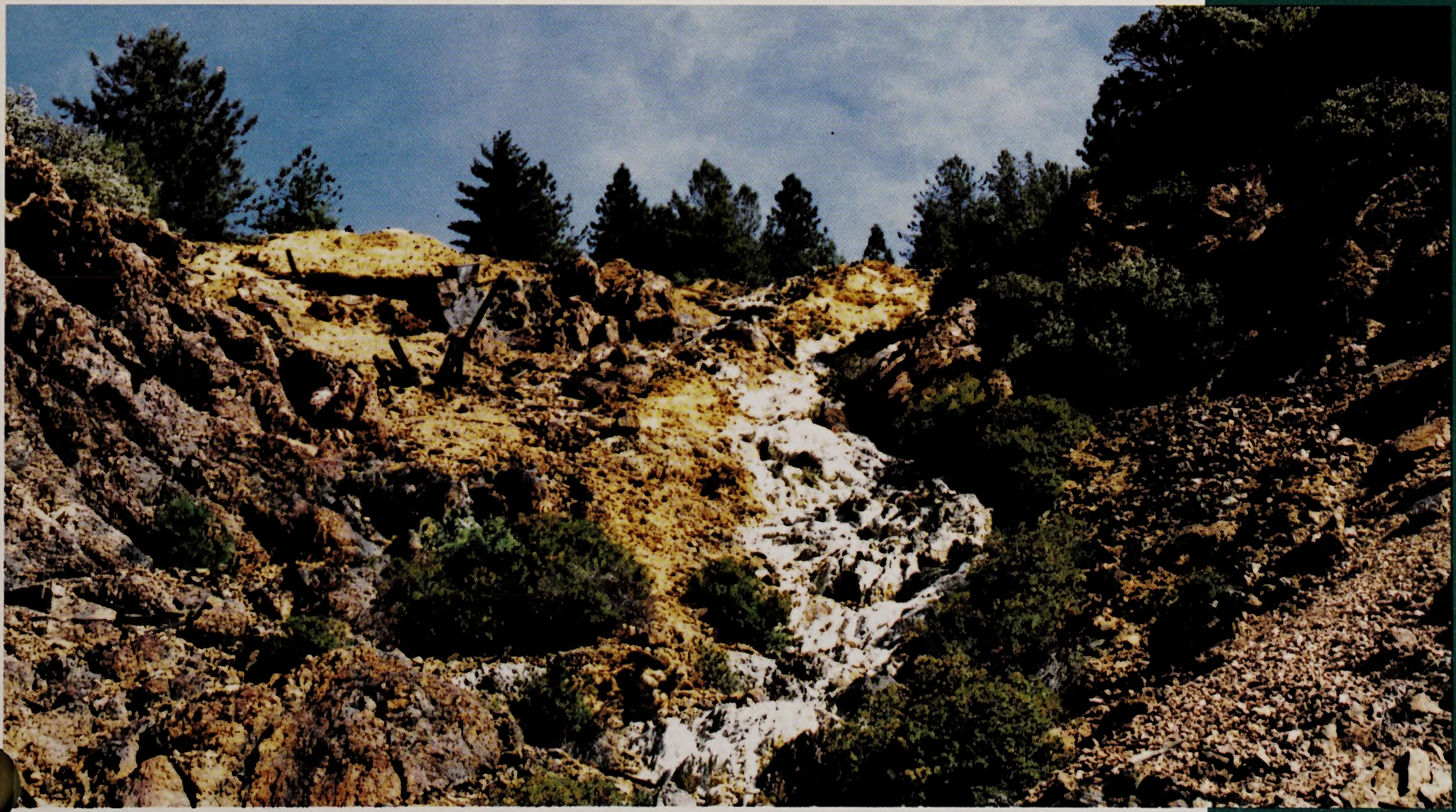
Figure 8
Highly acidic tailings, with high metals content, were released downstream following collapse of a tailings dam on the Rio Grande National Forest in Colorado.

Accomplishments To Date

Program accomplishments as coordinated by the joint agency working group include:

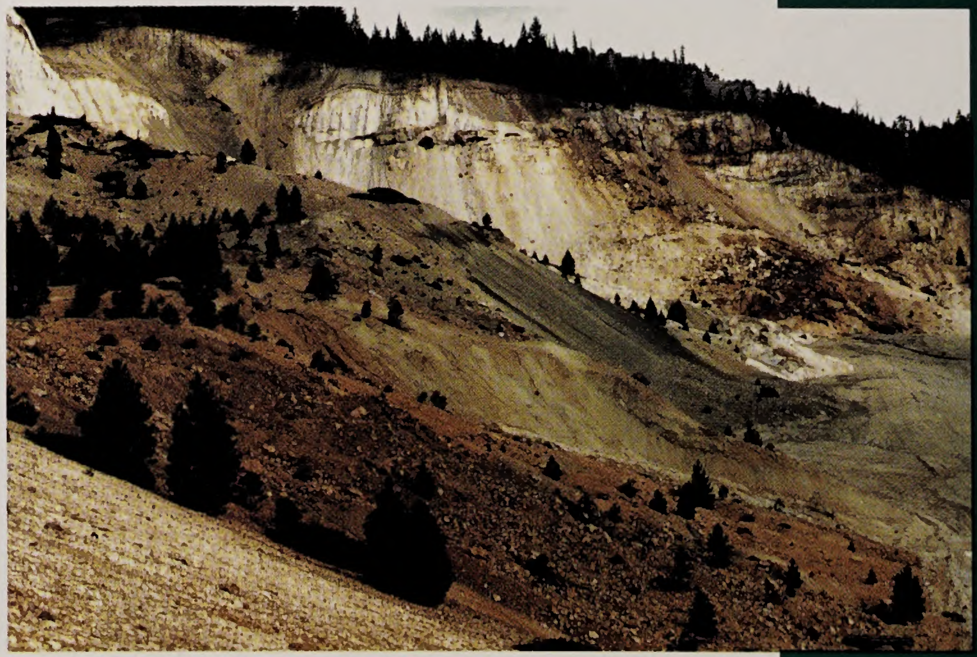
- Development of site selection criteria for cooperative Bureau of Mines / Forest Service research-related efforts.
- Establishment of a joint agency reconnaissance team for site evaluation and selection.
- Assistance in the control and treatment of acid drainage from the Golinsky Mine on the Shasta-Trinity National Forest.
- Sponsorship of and participation in a national acid mine drainage seminar for industry, land managers, and State and Federal regulatory agencies.

Figure 9
Acid drainage from an inactive gold mine runs down this hillside on the Shasta-Trinity National Forest in northern California. The acid flow has been the cause of fish kills further downstream.



Obviously, these accomplishments represent only a beginning and reflect limited funding. Much work remains to be done. The Forest Service and the Bureau of Mines are committed to moving ahead in this important work as fast as possible. The alternative to solving these problems at the pre-mining or mining stages of mineral development could result in unacceptably long long-term commitments to water treatment and site cleanup. In this age of environmental awareness, this alternative is of course unacceptable for current and future mining operations. Long-standing acid drainage problems from mines in the forests, many from operations before the national forests were set aside, are also in the public eye, with the expectation that an aggressive cleanup program will be pursued. The actions outlined in this publication are consistent with that expectation and are supported by the mining industry.

Figure Ten
Hillsides affected by mining in central California, Toiyabe National Forest. The acids generated in the soils of this old sulfur mine have severely slowed the rehabilitation of the area.



A cooperative

interagency

effort . . . aimed

at solving

acid drainage

problems.

Implementation of GIS for Water Resou
Planning and Management

By **Mark R. Leipnik,**[1] **Karen K. Kemp,**[2] and
Hugo A. Loaiciga,[3] Member, ASCE

Abstract: The geographic information systems (GIS) implementation process starts with the initial decision to use a GIS; proceeds through system selection, installation, and training; and up to data-base development and product generation. This paper discusses considerations related to each phase and focuses on other facets of GIS pertinent to water-resources planning and management. Many of these considerations involve critical choices that can pose significant challenges and impose substantial costs. An understanding of these challenges can expedite the GIS implementation process.

Introduction

Geographic information systems (GIS) is a rapidly evolving suite of technologies that consist of computer-based programs containing specialized algorithms and associated data-base-management structures, frequently in an integrated package. These systems are expressly designed to store information about the location, topology, and attributes of spatially referenced objects (such as rivers, wetlands, political boundaries, and roads). GIS can also provide analysis of the spatial properties (such as length, area, and perimeter) of these geographic objects. GIS can support many data-base queries tied to spatially referenced objects and their associated attributes. GIS systems also possess specialized spatial analysis functions, such as overlay of thematic layers and buffer-zone generation around objects. Also, most GIS systems provide for automated cartographic transformation and generation of graphic and cartographic products such as chloropleth and thematic maps. GIS systems provide other more-specialized spatial analysis functions: finding shortest paths in a network or calculating the areal extent of a watershed draining through a specified point given a digital elevation model (DEM).

Implementation related activities must precede full-scale project-oriented work. Phases of implementation identified in the literature (De Man 1988) include feasibility studies; selection of software, hardware, and peripherals; system installation; training; data conversion; data-base development; and finally preliminary product generation. A generalized flowchart of the GIS implementation process is presented in Fig. 1. We discuss each of these topics, along with other pertinent considerations such as accuracy of GIS

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[1] U.S. Bureau of Reclamation, Lower Colorado River Regional Ofc., Mail Stop LC 277, 400 Rail Road Ave., Boulder City, NV 89005; formerly, Grad. Student, Geography Dept., Univ. of California at Santa Barbara, Santa Barbara, CA.

[2] Coordinator of Education Programs, Nat. Ctr. for Geographic Information and Anal., Geography Dept., Univ. of California at Santa Barbara, Santa Barbara, CA 93106-1100.

[3] Assoc. Prof. of Hydro., Geography Dept., Univ. of California at Santa Barbara, Santa Barbara, CA.

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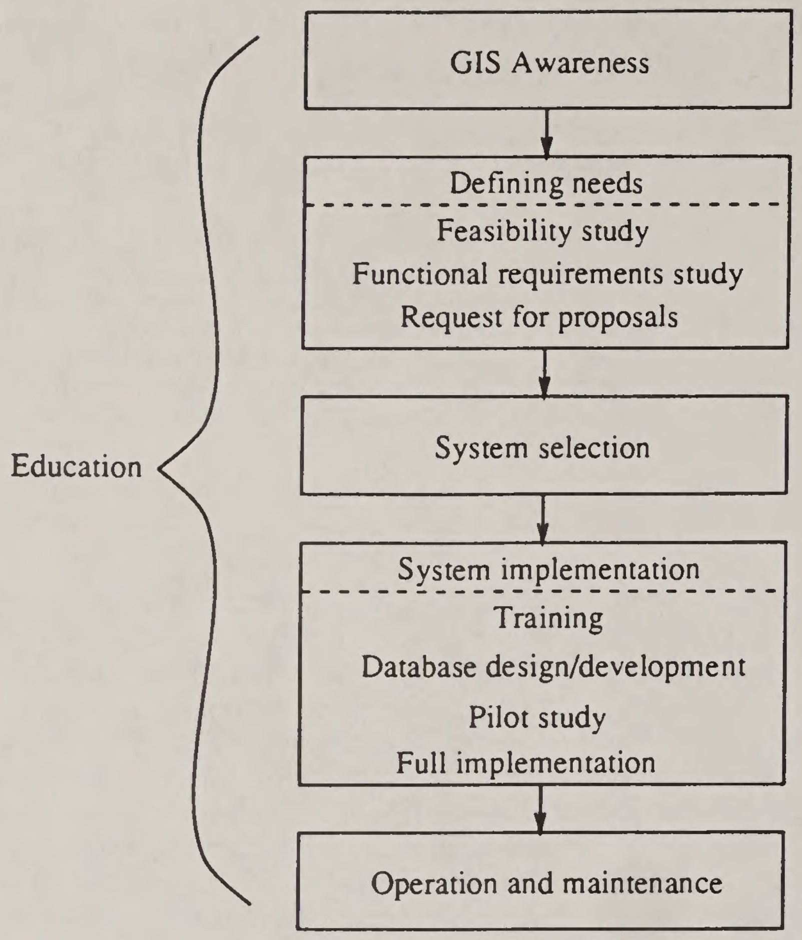

FIG. 1. Stages in the implementation of GIS

data, structure of pilot studies, and the need for GIS users to develop practical and theoretical knowledge of this rapidly changing technology.

BECOMING FAMILIAR WITH GIS

The busy manager or professional may find it easy to treat GIS as a black box that transforms existing hard-copy maps and tabular data into digital products. However, a paramount task of any new or potential GIS user is the early investment of time and energy in order to gain a solid general understanding of the character, capabilities, and costs of GIS.

Typically, GIS users get much of their information on GIS from software vendors. Although vendors can be a very useful source of information on the capabilities of their specific products their sales representatives often are unable to educate potential users on general principles and concepts of GIS. They seldom provide a complete assessment of the users' needs or explain how GIS can contribute to meeting them. As a result, many users gain only a smattering of knowledge, through trial-and-error use of a GIS package, relying on the vendor-supplied manuals for guidance.

Reference Books

It behooves the user or potential user of GIS to take the initiative to learn more about this rapidly changing field. Numerous and proliferating sources of information exist about GIS. Books on the subject of GIS include *Principles of Geographical Information Systems for Land Resource Assess-*

ment (Burrough 1986), the original GIS primer; *Geographical In[illegible]tion Systems: Principles and Applications* (Maguire et al. 1991), an exc[illegible]t and thorough two-volume set; *Geographic Information Systems: An Introduction* (Star and Estes 1990), which includes coverage of the relationship between GIS and remote sensing; *Introductory Readings in Geographic Information Systems* (1990), which has a wide range of reprinted articles about GIS; *GIS Applications in Natural Resources* (1991), which emphasizes forestry-related issues and; *Geographic Information Systems for Resource Management: A Compendium* (1989), which contains several articles on use of GIS in water-resources management.

Source Books

Source books of utility to the manager or researcher in search of knowledge about specific GIS solutions, systems and suppliers include *1991–1992 International GIS Sourcebook* (1991); *Intelligent Infrastructure Workbook: A Management Level Primer on GIS* (1990); and *Geographic Information 1991* (1991).

Journals and Trade Magazines

Several GIS journals and trade publications have appeared recently, including *The International Journal of Geographic Information Systems*, the primary scholarly journal in the field; *Cartography and Geographic Information Systems* (formerly, *American Cartographer*); *Photogrammetric Engineering and Remote Sensing*, which publishes a special annual issue on GIS; *GIS World*, the primary trade publication for GIS. Their annual survey of GIS software gives the best overview of software; and *Geo Info Systems*, a recent entry into the field, which is applications oriented.

Conferences

Annual conferences and expositions devoted to GIS and related subjects include GIS/LIS, hosted jointly by several professional societies; the Urban and Regional Information Systems Association (URISA) Conference; the American Congress on Surveying and Mapping and the American Society for Photogrammetry and Remote Sensing (ACSM/ASPRS) Conference; the EGIS (European GIS) Conference; the Association for Geographic Information (AGI) Conference; and numerous computer graphics and other specialty conferences.

Users Groups

Several users' groups for specific GIS systems hold annual meetings, including those of ARC-INFO, from Environmental Systems Research Institute (ESRI); MGE, from Intergraph Corporation; and GRASS. These meetings provide a forum for the discussion of specific GIS packages.

National Center for Geographic Information and Analysis

A valuable source of information on the latest research in GIS is the National Center for Geographic Information and Analysis (NCGIA). This National Science Foundation–funded research center is a three member consortium of the University of California at Santa Barbara (UCSB), the University of Maine, in Orono, Me., and the State University of New York, Buffalo, N.Y. The NCGIA sponsors research into key issues of GIS (such as accuracy of spatial data and spatial analysis), hosts conferences [such as the First Annual Conference on GIS and Environmental Modeling (Goodchil[illegible]., in press, 1993)], and has fostered the development of a core curri[illegible]m in GIS (*NCGIA* 1990). This internationally recognized 1,000-page curriculum, along with 60 other technical reports, is available from the NCGIA office at UCSB.

Specific Water Resource GIS Information

Information about specific water-resource-related GIS requires more effort to obtain. Most published material about GIS applications to water-resources planning and management is contained in conference proceedings (Leipnik and Loaiciga 1991) or presented in special reports (Wright and Buehler 1989). The references cited in this paper provide an excellent starting point for a more in-depth exploration of this topic. Other sources include publications from the United States Environmental Protection Agency (Aller et al. 1987; *Geographic* 1989), United States Geologic Survey (*U.S. GeoData* 1991), and other agencies, as well as vendors, consultants, service bureaus, and universities, whose role is discussed later.

DEFINING CURRENT AND FUTURE ROLE OF GIS

Once the natural-resources manager intent on employing GIS has gained a modicum of familiarity with the technology, he or she must consider the appropriate role for GIS. Even those users who already have established systems should periodically examine their requirements for GIS and determine if their current system continues to meet those needs. Many current users keep obsolete hardware, software, or both, perhaps to justify a prior capital investment.

A GIS is often acquired as part of a specific project with a very limited time frame and goals. Although this mode of GIS acquisition and use may conform to fiscal realities, results are often disappointing in terms of database development and product generation. The user who acquires a system with only one project in mind rarely gets a good return on investment, simply because GIS is such a versatile tool if properly applied. The development of a GIS for a specific application can often support other analysis or management activities that utilize the same data base. For example, digital soil-survey data developed for agricultural applications can be used in water-quality studies, or vice versa (Howard and Barr 1991).

GIS often leads to changes in the way analysis and modeling of groundwater flow or rainfall-runoff relationships are performed (Harris et al., in press, 1993; Richards et al., in press, 1993). This technology encourages new forms of data input and display of results (Maidment, in press, 1993). Researchers are changing the fundamental structure of their models to take advantage of spatially distributed parametrizations, replacing the traditional lumped-parameter models (Fedra, in press, 1993). Therefore, the role of GIS should be defined both in terms of supplementing or replacing current organizational functions (such as manual cartography) and also in terms of future possibilities.

Feasibility Studies

Before committing resources to the acquisition or upgrade of a GIS, the prudent manager will perform a study of what the system will be used for and what resources are currently used to perform those functions. That study can be an informal internal discusion, or a full-scale cost-benefit analysis conducted by a highly specialized consulting firm. It is desirable, however, to have an objective party provide insights into this process.

Feasibility studies are difficult because many factors relevant t[illegible]nalysis are uncertain. The state of the technology is constantly evolving [illegible] terms of functionality and costs; the new generation of workstations are orders of magnitude more powerful and significantly less expensive than their mainframe predecessors of past years, many of which are still running GIS packages. Regulatory demands facing resource managers, though often uncertain, are generally becoming more stringent. For example, the definition of what constitutes a wetland and what protections are required are in a state of flux. Finally, the availability of funding is tenuous and likely to be further constrained in the near future.

The decision not to adopt or upgrade a GIS, and to continue to rely on past practices, is deceptively easy to quantify in terms of costs and results. The costs of traditional methods of resource inventory, cartographic database access and query (searching through a filing cabinet or map file), and manual cartography are easily determined, though they are high in terms of skilled personnel time (Couch 1991). The results of traditional methods are also known; but when compared with the graphic impact, speed, and analysis capabilities afforded by a properly implemented GIS, the old methods are often judged inferior by a rapidly growing number of resource managers (Dickinson and Calkins 1988).

Functional Requirements Studies

A useful part of the GIS adoption decision process is a functional-requirements study (FRS). An FRS details the products to be produced by the GIS, the required data and the GIS functions that must be available. An FRS can be used to define the scope of the project and the basic structure of the implemented GIS. If the FRS is properly performed, it can become the primary planning document for the rest of the GIS implementation process and the basis of a request for proposals (RFP). The FRS phase has received considerable attention from GIS consultants. Highly structured methodologies for conducting the FRS have evolved, including the use of interviews, focus groups, and questionnaires.

Request for Proposals

Once a functional-requirements study or other feasibility study has been conducted, the GIS acquisition process can begin. The best way to handle GIS acquisition is to develop a request for proposals (RFP). An RFP should not be so narrow that it suggests only a single software solution; it should describe in detail the nature of the proposed data-base contents, the functions needed to create and manipulate the data base, and the products that are anticipated. Since a GIS represents a considerable investment of resources, a thorough study of available alternatives should be made before selecting any system. The RFP should be distributed to as many vendors as possible. Their replies should specify details of graphical representation (topological vector, raster, etc.), system functionalities, available interfaces to data sources, data-base-management systems, network and comunication protocols, and hardware compatibility. The results from a well-structured RFP should give management the information needed to make informed and defensible decisions.

SELECTING APPROPRIATE SOFTWARE AND HARDWARE

GIS Software

Today, the characteristics of the GIS are largely determined by software vendors. A sampling of popular GIS packages is presented in Appendix I.

Cur[illegible] private companies ranging in size from multinational corporations like IBM and Hitachi to single proprietorships dominate the GIS market.

University-developed software: Several GIS packages developed by universities primarily for educational purposes provide inexpensive alternatives. The raster-based GIS package IDRISI (Clark University, Worcester, Mass.) is perhaps the most popular example of this class of software. IDRISI is somewhat limited in functionality, yet it is an excellent educational tool and is continually being enhanced. Other examples include MacGIS (University of Oregon, Eugene), OSU-MAP (Ohio State University), and MAP II (University of Winnipeg, Canada).

Government-developed software: Government agencies are involved in GIS systems development. The U.S. Army Corps of Engineers Construction Engineering Research Laboratory (CERL) is notable for its Geographic Resource Analysis Support System (GRASS). GRASS is a raster-based product that has been widely applied to water-resources and environmental-impact-assessment applications. It is well supported and runs on many platforms. Several private vendors have developed sophisticated user interfaces for it. Linkages to various hydrologic models are being actively developed. GIS users likely to interact with the Corps could benefit from using GRASS.

Private-sector software: Cost of this software runs the gamut from several hundred dollars to several hundred thousand dollars. Scope ranges from large, fully integrated products offering most of the spatial analysis and representation possibilities available, to limited packages geared to specific applications such as automated mapping/facilities management (AM/FM), accessing and analyzing U.S. Census Bureau TIGER files, and analysis of remotely sensed imagery (*1991* 1991).

ESRI's ARC/INFO: The vector-based GIS package ARC/INFO [Environmental Systems Research Institute (ESRI), Redlands, Calif.] is very widely used. ARC/INFO helped to establish the market for GIS, and has more installations on more platforms serving more applications than any other available package (*1991* 1991). Mainframe, PC, and UNIX workstation versions of ARC/INFO are available, as are interfaces to many data sources, models, and data-base-management systems. The latest version of ARC/INFO addresses limitations of earlier versions with respect to the handling of attribute data and provides facilities for developing a graphical user interface. Independently developed software provides linkage capabilities between the INFO flat-file data-base-management system and relational data bases such as Oracle, INGRES, DB2, and Sybase. Limitations of vector-based systems such as handling of fuzzy data or use with applications such as fire-spread modeling are addressed by a new raster-based package from ESRI called GRID.

ARC/INFO is relatively complex, requiring a significant commitment of time and effort to use effectively. However, many successful applications of this system to natural-resources management demonstrate its utility to committed users. In the water-resources field ARC/INFO has been linked to such models as the Hydrologic Engineering Center's HEC 1 and HEC 2 models and other hydrologic models (Maidment, in press, 1993), to river basin models (Grayman et al. 1991), ground-water models such as MODFLOW (the U.S. Geological Survey's ground-water flow model), other subsurface flow and transport models (More et al., in press, 1993), and to finite-element contaminant transport models such as the coupled fluid energy solute-transport (CFEST) model developed by CH$_2$M Hill (Harris et al., in press, 1993).

Intergraph's MGE: Another highly functional GIS software p[illegible]t to[illegible]e is Intergraph's Modular GIS Environment (MGE) software product, and related modules such as Modular GIS Analyst (MGA) (Intergraph Corporation, Huntsville, Ala.). As the names indicate, this software is organized into modules, so users need purchase only those modules relevant to their needs. MGE is a vector-based package with raster-supporting modules designed to operate in conjunction with Intergraph's Microstation 32 computer-aided design (CAD) package, and it offers the best available integration of CAD and GIS software. MGE has the ability to interface with numerous relational data bases, including ORACLE, INFORMIX, INGRES, and DB2. Specialized modules include three-dimensional computer-aided design (CAD), sewer management, contamination-site management, geophysical modeling, and other hydrologic applications. MGA is a module that supports spatial-analysis functions. These products were developed for the Intergraph UNIX-based workstation (a microcomputer version also exists).

Interfaces between MGE, and MODFLOW, AT123D (a contaminant-transport model developed by the Department of Energy), and statistical packages (such as 20/20) are included in MGE's environmental resource management and assessment (ERMA) system module. This module has been used to support hydrogeologic investigations at contamination sites including military facilities such as Vandenberg Air Force Base, Calif., and the Patuxent Naval Air Station, Md. MGE has also been used for water-resource-management activities by the Michigan Department of Natural Resources (Michael 1991).

Other GIS software: Other GIS packages used for water resources management include the following.

The INFOMAP system, from Synercom (Houston, Tex.), a vector-based package, has been used in a number of very-large-scale water-resource-related projects and linked by Woolpert Consultants (Dayton, Ohio) to the Storm Water Management Model (SWMM) (Cowden 1991).

The AGIS system, from Delta Data Systems (Picayune, Miss.), has been used to model flooding, using a variety of raster and vector input data.

SPANS, from TYDAC (Arlington, Va.), a raster- and vector-supporting package, is widely used in natural-resource-management applications, notably forestry.

MOSS, developed by the Bureau of Land Management and now available from Autometrica (Lakewood, Colo), is a vector-based package used in resource-management applications by government agencies.

GEO/SQL from Generation 5 Technologies (Denver, Colo.) is vector based, with limited spatial-analysis functions; it uses AUTOCAD as a front end and is linked to several structured query language (SQL) based relational data bases. GEO/SQL has been used to support ground-water contamination studies and in public water-supply-system-management applications.

The Earth Resource Data Analysis System (ERDAS, Inc., Atlanta, Ga.), developed for the display and analysis of remotely sensed imagery, is a useful component of a GIS relying heavily on remotely sensed data. ERDAS has been used in numerous environmental studies, including analysis of areas to be inundated by potential dam sites (Mitasova and Iverson 1991; Baffes et al. 1990).

Many other commercial GIS packages have been developed. The annual

GI[illegible]*d* software survey provides details on 150 different packages (*1991* 1991).

GIS versus Computer-Aided Design (CAD) and AM/FM

Some of the software products listed in the *GIS World* software survey are limited in terms of GIS functions such as spatial-analysis capabilities (for example, buffering and polygon overlay) and are more properly termed CAD packages. CAD output and GIS output may look similar, but the structure and function of CAD and GIS systems is very different. In the writers' opinion, users should avoid the temptation to use a CAD package and a separate data base as a proxy for a GIS. The nature of data storage in available CAD packages severely limits query of the data base, spatial analysis, and handling of cartographic transformations. Automated mapping/facilities management (AM/FM) software comes closer to GIS software in terms of its attribute data-handling capabilities, but generally lacks sophisticated spatial-analysis capabilities. However, for specific applications such as water-distribution-system mapping and maintenance, AM/FM software may be more appropriate than sophisticated GIS software, which offers the user functions that may not be needed or that may be overly complex for some users (Cowen 1990).

Spatial Decision-Support Systems

High-powered interactive systems running GIS and linked to hydrologic and other models and to decision-support tools such as expert systems, statistical packages, optimization programs, and enhanced graphics offer the natural resources manager a new paradigm for environmental analysis. This integrated approach is termed spatial decision-support systems (SDSS). This new technology is being used to support a wide variety of applications (Fedra, in press, 1993). The role of water-resource engineering in the evolution of SDSS will be highlighted in an Engineering Foundation conference on the application of spatial decision support systems to water resources management and planning that is scheduled for 1994, in Santa Barbara, Calif.

Computer Platforms

Personal microcomputers (PCs) versus mainframes: Just as with software, there are a number of choices available to the user for computer hardware. Personal micro-computers are easy to use and inexpensive. However, the large data sets with complex topology and numerous attribute relationships encountered in typical resource-management GIS applications imply that PCs may offer inadequate power. Until recently, serious GIS users were forced to run GIS programs and maintain their attribute data bases on mainframe computers, many of which had proprietary operating systems requiring GIS software specific to that machine. Mainframes have several disadvantages when it comes to GIS, notably complex operating systems, the need to support other tasks, and potential problems with end-user access to the system. However, some users may find the data-handling capabilities of mainframe (and mini) computers desirable and even essential for very large data sets.

Workstations: UNIX workstations appear to be the GIS workhorses of the 1990s. They offer an excellent compromise between the ease of access and simplicity afforded by a PC and the power of a mainframe. The rapidly increasing power and the relative affordability of workstations now provide the user access to powerful GIS coupled to large and complex da[illegible]t to and other decision-support tools such as hydrologic models, statistical p[illegible]ages, and optimization programs, on stand-alone or networked desktop platforms.

Peripherals

The optimal choice of peripherals will depend on the character of the inputs and outputs anticipated from the GIS.

Storage media: Typically include floppy disks, tape cartridges, reel-to-reel tapes, and various types of optical disks. Magnetic tape is an effective means of storing and transferring the large data sets encountered in GIS. However, data on magnetic tape must be read sequentially and the longevity of data stored on tape is limited. The character of tape media can be expected to change with the recent introduction of digital audio tape (DAT). Given the large size of the GIS datasets, compact disks (CDs) are particularly effective as a data storage and transfer media. Some GIS input data are already available in a CD read-only memory (ROM) format and more will be available soon (Lytle, in press, 1993). The erasable optical disk offers perhaps the best available medium form GIS data storage, access, and transfer, but this technology is still costly.

Digitizing versus Scanning

Data input and conversion devices include keyboards, scanners, and digitizer tablets. Digitizing involves a human operator who manipulates a line-following device (a puck or cursor) on a digitizer tablet, manually tracing line work from a map or engineering drawing and keying in the related attribute data simultaneously or subsequently. Scanning employs laser optics to automatically store the map or drawing as a digital image. The process involves less initial manual labor, although extensive computer and manual editing of the data may be required. Scanning is more rapid but more technologically intensive. The nature, quantity, and quality of the input data will help to determine which conversion approach is more appropriate. If scanning is deemed preferable, specialized service bureaus exist that can perform this activity, saving an end-user the substantial cost of acquiring drum scanners and related software (Armstrong 1991).

Output Devices

Some type of graphics-output device will be required by most users. An eight-pen color roll-type plotter or flatbed plotter is typical. If "fill" is desired on cartographic products, an electrostatic plotter may be more appropriate. Color thermowax printers and color inkjet printers offer another excellent output device for smaller-size graphics. Color output devices cost more than black-and-white and gray-scale devices, but they are well worth the investment if the output is going to be presented to outside parties or senior management.

Compatibility

Compatibility of hardware and software can be a serious problem with peripheral devices such as digitizer tablets or plotters. Generally speaking, a hardware-specific software driver is required to use any external input or output device. Some drivers for specialized equipment such as electrostatic plotters can be quite expensive; other peripherals simply may not be supported by a given software package. Before a GIS package or peripheral is acquired, intercompatibility should be confirmed.

Sy[illegible]stallation

Once acquired, the GIS must be installed in its new operating environment. Getting a GIS system up and running can be a time-consuming task that requires input from highly trained consultants, or it can be as simple as putting a disk into drive A. In most water-resource-related applications, installation of the GIS software will probably require the assistance of several GIS experts, technicians, a data-base administrator, and technical assistance from the vendor.

Training and Human Resources Development

Since GIS is a relatively new technology, individuals with a strong background in its theoretical foundations and the necessary specific technical skills are rare. In many organizations, existing personnel—particularly cartographers and drafting personnel—will be retained (and ideally retrained) as "GIS specialists." Although this approach has many practical benefits, it can lead to serious problems. A significant difference now exists between the technical background necessary to master a PC-based CAD package (such as AUTOCAD) and the far more rigorous prerequisites of mastering a complex GIS.

Water-resource engineers and other in-house professionals can often become proficient GIS users who have the advantage of a thorough understanding of the sources and uses of the data and other GIS products. However, further specialized training may be needed in order to develop this expertise. Also, a change in attitudes about the ease and speed with which a GIS can be implemented may be in order. There are many tedious aspects associated with data-base development and product generation. Manual digitizing, is a very time-consuming task and requires great patience as well as some understanding of system commands. The entry of attribute data, which has lesser technical requirements, can be even more tedious. Map production requires considerable cartographic design background as well as patience with hardware quirks (Armstrong 1991).

Managers may also benefit from learning about GIS on a conceptual level. In this case, education rather than training (learning associated directly with operating the system), is more appropriate. In GIS education, considerations such as the sources and quality of spatial data, spatial analytical concepts, and the multitude of problems to which GIS can be applied should be stressed.

To develop GIS expertise, some form of structured training is generally needed. Software vendors generally offer well-designed training courses that teach the specific commands needed in their software package. However, vendors offer limited education in the general aspects of GIS and little or no coursework in water-resource-related aspects of GIS. The cost of vendor-sponsored training programs often inhibits learning about GIS fundamentals.

Educational courses in GIS are offered by universities and colleges (often through geography departments). However, these regular courses of study, though less expensive per hour than many vendor training programs, may take unacceptable amounts of personnel time. Moreover, regular GIS curricula seldom provide specialized study in water-resource applications of GIS. University- and consultant-sponsored GIS workshops offer a good alternative. A week of intensive and targeted study of GIS can make the investment in GIS software and supporting hardware worthwhile. The common complaint that the vendor training swamps underprepared participants can be mitigated by prior exposure to GIS fundamentals and [illegible]t to [illegible]nal-data-base and operating system concepts. Also, a GIS workshop can be structured to meet the specific needs of a user.

In large organizations, responsibility for the GIS may be assigned to the existing computer-systems data-base-management group. This approach usually assures that the technical aspects of the operating system, the character of the attribute data, and other functional parameters of the system are well comprehended. However, GIS is not yet a normal part of information-science curricula. Therefore, the nature of spatial data, the special characteristics of spatial-analysis algorithms, and the character of cartographic products may initially elude these traditional custodians. Furthermore, if the GIS is entirely in the hands of a computer-systems group, it may not be disseminated into the organization, leading to underuse.

An interdisciplinary approach is perhaps a more desirable (albeit difficult) solution, because of the diverse talents needed to utilize a GIS optimally. GIS should function as an integrating technology, allowing individuals and departments that previously worked autonomously to interact in new ways. An interdepartmental team composed of professional engineers, systems analysts, cartographers, data-entry operators, and others is probably best able to meet the challenges posed by GIS implementation and development. The more that team members are aware of concepts from other disciplines, the more satisfactory the outcome is likely to be.

An important practical consideration is that any employee who develops specialized expertise in GIS becomes a valuable commodity in the labor market. Therefore, some adjustment of status and/or job title within the organization may be warranted in order to retain individuals with GIS expertise.

Pilot Studies

Once a system has been acquired, installed, and tested and trained personnel are available to operate it, the data-base-development and product-generation process begins. Rather than launch into development of a GIS covering all aspects of the resource-management problem under consideration, it is advisable to select a representative geographically circumscribed "slice" of the overall area or problem for use in a pilot project. Pilot studies must have realistic and specific goals and timetables and should be designed to rapidly generate modest, yet representative, products, such as site-specific maps or sample data-base schema. Such products can be a tangible demonstration of GIS capabilities and will help to encourage a further investment in longer-term GIS development. A pilot project will also allow system administrators to gauge more accurately the costs of data-base development.

Data Sources, Accuracy and Data-Base Development

Sources of digital data: The most time-consuming part of the GIS implementation process is data-base development. Many organizations turn this function over to specialized service bureaus or other consultants, with obvious benefits. Fortunately, an increasing quantity of input data is now available in digital form. For example the Census Bureau's TIGER files provide street-map data and census-tract boundaries for the United States, the U.S. Geological Survey (USGS) has digitized most of its 1:100,000 topographic map sheets (and many 1:24,000 quad sheets), and private parties offer many types of digital cartographic data as well (*1991* 1991). The Defense Mapping Agency offers the 1:1 million digital chart of the world, and the [illegible] Conservation Service is converting its soil survey maps to digital form (Lytle, in press, 1993). Many of these products will be available in CD ROM format. Also, the U.S. Environmental Protection Agency (EPA) and other federal agencies make available much digital data in tabular form, such as water-quality data, that may be usefully incorporated into a GIS. Statewide GIS data bases on water resources are being developed in many states, including Minnesota, Massachusetts, Connecticut, Rhode Island, Texas, California, and New Jersey. Various local agencies in most states have developed GIS data bases, many of which are being shared among multiple users (Marshall et al. 1990). Unfortunately, the contents, formats, standards, and coverage of these data sets are often not uniform, and finding the specific source of digital data for a given area and theme can be difficult. The federal government has recently adopted the Spatial Data Transfer Format (SDTF) as a Federal Information Processing Standard (FIPS) to standardize formats for all federal spatial data. Also, the newly established nationwide network of 75 earth science information centers should provide a one-stop source for U.S. government spatial data (Kemp, in press, 1993).

Spatial data accuracy: This is an important and very active area of research in GIS. The accuracy and precision of different sets of digital data vary considerably. The integration of data with diverse formats and scales requires conversion prior to use. The conversion process introduces biases and errors that may be hard to quantify and rectify. Many functions within a GIS can produce results that are spurious, given imprecise input data. For example, a polygon overlay operation frequently produces numerous tiny, "sliver" polygons. These problems are of more than academic interest, because data in a GIS may be used in certain engineering or other applications in which accuracy is critical; also, data in a GIS may become the subject of litigation (Epstein and Roitman 1990). Therefore, it is important for GIS users to keep track of the history and character of data sources and manipulations. Provision for the retention of this "metadata" recording the "lineage" of the digital data should be built into the evolving data-base schema. For a more-detailed discussion of spatial-data accuracy see Goodchild and Gopal (1989).

Data-base design: The data base should be a key product and center of attention during the GIS development effort. Colorful graphics and hard-copy products such as maps may have a powerful visual impact and utility, but the real value of the GIS is determined by the underlying data and analytical functions, which allow that data to be used to make decisions. Besides the spatial data, data bases should contain attribute information for spatial objects, data on cartographic characteristics such as scale, projection and symbology, and appropriate links between tables and/or objects within the data base. Data-base development ideally should involve the creation of several views that support the special needs of different users. These views can be supported by careful structuring of the evolving data-base schema. Data-base design can be facilitated by techniques such as the entity-relationship approach (Teorey 1990).

Distributed data bases: As the size and complexity of a data base increases or when multiple users at dispersed locations wish to share some or all of the data in a GIS system, the physical location of and ease of user access to a system become considerations. With the advent of local- and wide-area networks, distributed data-base-management system (DDBMS) have become practical. In one DDBMS scenario, a central data base would be maintained on a mainframe at a headquarters location, while regional offices would extract and manipulate the portion of the data base [illegible]t to their needs. Field offices would employ PCs to run less-powerful GIS software, which would access an even more limited data base. Localized changes in attribute or location data could be updated at the field-office level and sent by network up the organizational and data-structure hierarchy. Analytical results and more regional data input (remotely sensed data, for instance) could be divided into relevant geographic "views" at the central office and sent back to regional and field offices. Such rapid updating of data-base contents via the network creates a highly interactive environment [see Reed (1991) for a discussion of a forestry application].

Product Generation Issues

The central role of the data base as a GIS product has been stressed. Of course traditional products (and some unconventional ones) can also be generated by the GIS. Maps, engineering drawings, color slides, and overheads are the most familiar graphical products produced using a GIS. Reports based on the attribute data are another important product. Fortunately, these reports need not be reams of incomprehensible alphanumeric output. Interfaces between GIS packages and spreadsheets and statistical packages allow the user to generate histograms, graphs, charts, and tables from data contained in the GIS. As with all graphical products, the emphasis should be on impact and comprehensibility.

ROLE OF ACADEMICS, VENDORS, CONSULTANTS, AND SERVICE BUREAUS

Since the whole GIS field is in a rapid state of flux, the roles of the varied GIS players are evolving, and frequently overlap. Convoluted yet fruitful collaborations of people from organizations of very different types are occurring. In addition to the organization adopting GIS technology, there are four other distinct categories of players in the GIS game: academics, vendors, consultants, and service bureaus.

Academics

Academics primarily contribute through their work in research and teaching. Research includes work on GIS data structures, development of new and expanded applications of GIS and integrated spatial decision-support systems, and three-dimensional representation and dynamic modeling capabilities within GIS (Hazelton et al. 1990). In addition, academics do some project-related work for government agencies.

Vendors

GIS software vendors do the largest portion of systems-development work. Vendors provide varying levels of support to users, depending on the company, the complexity of the product, and the willingness of the user to pay. In some cases, software may be so complex that use of a vendor-supplied consultant is a prerequisite for its installation. Some value-added retailers develop specialized accoutrements to existing packages. These might include a customized graphical user interface or a data interface to an existing modeling package or data base.

Consultants

Consultants can offer important assistance at several points in the GIS implementation process. They provide invaluable advice on system selection and cust[illegible] training. Consultants help develop specialized interfaces between G[illegible] systems, models, and/or data sources. Consultants provide one of the most cost-effective ways of obtaining GIS expertise, if it is only needed at a few critical junctures during implementation. GIS consultants run the gamut from one-man operations to multinational engineering firms (such as EBASCO or CH_2M Hill). Selection of the right consultant is a delicate decision and, in fact, a few consultants exist whose stock-in-trade is advising users on which GIS consultants they should retain.

Service Bureaus

Service bureaus primarily specialize in the often onerous task of assembling, converting, and creating GIS data bases. These firms have access to costly equipment such as large drum scanners, banks of digitizer tablets, and data-input terminals, all staffed by skilled operators. Acquiring such facilities is not cost-effective for most users. There are, however, several potential drawbacks involved in use of service bureaus. First, their services are expensive, especially for small projects. Second, the quality and content of material going into the data base is not under the direct purview of the ultimate users. Since the service bureau may not be familiar with the characteristics of the location from which the data are being acquired, obvious errors may go undetected until the data are deeply imbedded in the GIS and have been used to generate a product. Correction of such inadvertent errors will, of course, add additional delays and costs. To minimize these types of errors, close contact between the end-user and the service bureau should be maintained.

SPECIAL ISSUES PERTINENT TO WATER RESOURCES MANAGEMENT

Water-resources management has proved a fertile field for GIS technology. Linkage of GIS to computer models is particularly prevalent for surface and subsurface hydrologic applications. Nevertheless, GIS use in water-resource management currently lags behind that in forestry, urban and regional planning, resource inventory and assessment, land and cadastral information, and AM/FM in terms of numbers of users and applications. However, these other applications also involve water resources. Given the critical role of the hydrosphere in the human and natural environment in areas of abundance (and more so in areas of scarcity), management of water is central to the management of environmental problems. In turn, representation and analysis of water-related phenomena by GIS facilitates their management. Thus, it seems likely that GIS use will continue to proliferate in this area.

Raster versus Vector Considerations

Unique aspects of water and water-related problems suggest a special approach for their handling in a GIS. Most GIS are either raster- or vector-based systems. Systems claiming both capabilities generally convert data from the secondary form to the primary form prior to analysis. Often this produces a consequent loss of accuracy, precision, or both. As a rule, raster-based packages are more appropriate for management, inventory, analysis, and representation of resources that are distributed continuously across the landscape, such as forests and soils. Raster-based packages are also appropriate when the primary input data come in a raster format (such as remotely sensed imagery). Vector-based systems are more appropriate in applications in which the locations of objects such as roads, sewers, or [illegible]al boundaries are defined precisely. Vector-based packages are also appropriate when vector inputs such as CAD data or drafted engineering drawings are employed.

Water-resource-related data can have high precision (e.g. sewer locations) or they can be fuzzy (e.g. wetland perimeters). Even objects such as rivers that are precisely represented on maps are often in reality highly variable. This suggests that the high precision afforded by vector-based GIS may be inappropriate. Conversely, raster representation can give objects a blocky appearance unsuitable for depiction of many features, particularly linear ones.

In any given water-resource-related project, all the foregoing considerations may appertain. For example, an aqueduct or pipeline project might best use a vector-based GIS for the hydraulic engineering and pipeline-corridor-construction phase, and a raster-based GIS for the environmental-impact-assessment study of the right-of-way area. Which type of package is most appropriate would depend on the specific application. Perhaps more than one GIS program would be optimal, although that implies learning more commands and/or additional acquisition costs and overcoming data-conversion and transfer problems.

Spatial Analysis Functions

Both raster- and vector-based GIS software have many spatial-analysis capabilities. Those most likely to be of interest to water-resource managers include area, length, and perimeter calculation; overlay of thematic layers; and buffer-zone generation. Buffer-zone generation is particularly suited to risk and/or impact assessment for objects or facilities with known locations. Several investigators have used a GIS to construct buffers around the locations of wellheads and the locations of known or potential contamination sites to facilitate risk assessments for wellhead-protection purposes. Overlay of thematic layers is useful for impact assessment or general site selection using spatial intersection of several different environmental themes (e.g. proximity to sensitive riparian habitat, slope, vegetation, soil type). Data layers maintained in the GIS, containing information on such regional acquifer parameters as depth to ground water, net recharge, aquifer characteristics, soil characteristics, topography, impact of the vadose zone, and hydraulic conductivity (the DRASTIC method variables) are used for aquifer-vulnerability assessment. Overlay of these layers coupled to buffer-zone generation around point sources of pollution is ideally suited to facilitating such aquifer-vulnerability assessments (Aller et al. 1987; Evans and Myers 1986).

Characteristics of Water Resources Data

Data used in water-resource management also have special characteristics. Most hydrographic data represent some nominal static average depth, shoreline perimeter, stream centerline, and so forth. Water bodies vary in their boundaries and properties: estuaries vary daily, rivers vary seasonally and in response to storm events, and large lakes may vary over decades. Temporal variability and indistinct boundaries are not well handled in current GIS systems. Dynamic phenomena may be represented by taking snapshots at several time intervals and running them sequentially to create a computerized movie, something that is only recently feasible. Recently it has been suggested that fuzzy data might be represented by showing regions with [illegible] values in intermediate colors, for example if open water is shown [illegible] and dry land is shown in red, then wetlands might be represented in purple, with appropriate levels of color saturation and hue for areas of transition.

Representing Surfaces and Subsurface

Hydrologic and hydrogeologic applications of GIS often require representation of the earth's surface and subsurface. Rainfall/runoff-simulation applications require representation of the earth's surface. Various digital elevation models including those using grids, triangulated irregular networks (TIN), or contours are available for surface representation (Weibel and Heller 1991). Which model is appropriate depends largely on the nature of the terrain and the analysis performed. Rugged terrain may be more realistically repesented with a TIN, and, conversely, a grid model may be more appropriate to gentle terrain. Modeling of flow across a surface is more dynamically correct in contour-based models, easy but only approximate on grid-based models, and problematic on TIN-based models (Maidment, in press, 1993).

Hydrogeologists are concerned with the representation of the earth's subsurface, and hence with the need to represent cross sections, fence diagrams, stacked surfaces, and true three-dimensional volumes (*Three* 1989). The latter problem is beyond the capabilities of any existing commercial GIS package. Wire-frame models and other surface models as well as software capable of displaying geologic cross sections and borehole geophysical data (provided in products such as the PRE/MIER and EP/SECT modules from Intergraph and GEOBASE from Earthware) are the best proxy for true three-dimensional (3D) GIS currently available. However, "true" 3D software originally developed by firms such as Dynamic Graphics (Alameda, Calif.), primarily for the visual analysis of subsurface phenomena for exploration and production in the petroleum industry, is now increasingly being applied to environmental problems like the representation of subsurface contaminant plumes. These programs allow true three-dimensional volumes to be represented and manipulated, although the association of nongraphic attributes and access to spatial-analysis functions are limited (Webster-Scholten 1990).

CONCLUSION

Many challenges are associated with each distinct phase of GIS implementation. Considerations related to GIS implementation within a water resource management and planning context have been emphasized. Awareness of these considerations and the growing range of solutions now available will assist current and potential GIS users deal with the many difficult environmental, land- and facilities-management issues facing water-resource managers and planners.

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APPENDIX I. SOFTWARE

Comparison of GIS and related software; analysis functions are assessed in the following order: buffer, map algebra, surface, network, polygon, and image processing (T = has the function; F = does not have the function) (*1991* 1991).

Az Mnt GIS
- USGS

Name: Atlas*GIS
Company: Strategic Mapping, Inc.
Cost: $1,000s
Operating systems: DOS
Platforms: PC
Structure: Nontopological vector
Analysis: T,T,F,F,T,F

Name: ARC/INFO
Company: Environmnental Systems Research Institute
Cost: $1,000–10,000s
Operating systems: UNIX, DOS
Platforms: PC, workstation, mini
Structure: Topological vector with raster
Analysis: T,T,T,T,T,T

Name: ERDAS
Company: ERDAS, Inc.
Cost: $1,000s
Operating system: UNIX, DOS, VMS
Platforms: PC, workstation, mini
Structure: Raster
Analysis: T,T,T,F,T,T

Name: GEO/SQL
Company: Generation 5 Technology, Ltd.
Cost: $10,000+
Operating system: UNIX, DOS
Platforms: PC, workstation
Structure: Topological vector
Analysis: T,T,T,T,F,F

Name: GRASS
Company: U.S. Army Corp of Engineers
Cost: free to $1000s
Operating system: UNIX
Platforms: PC, Mac, workstations, mini
Structure: Raster
Analysis: T,T,T,T,F,T

Name: IDRISI
Company: Clark University

Cost: $1
Operating system: DOS
Platforms: PC
Structure: Raster
Analysis: T,T,T,F,T,T

Name: Interactive Surface Modeling
Company: Dynamic Graphics, Inc.
Cost: $10,000s
Operating system: UNIX, VMS
Platforms: workstation, mini
Structure: Nontopological vector
Analysis: F,T,T,F,F,F

Name: MAP II
Company: John Wiley and Sons
Cost: $10–100s
Operating system: Mac
Platforms: Mac
Structure: Raster
Analysis: T,T,T,T,T,T

Name: MapInfo
Company: MapInfo Corp.
Cost: $100–1,000s
Operating system: UNIX, DOS, Mac
Platforms: PC, Mac, workstation
Structure: Nontopological vector
Analysis: T,T,F,F,T,F

Name: Modular GIS Environment
Company: Intergraph, Inc.
Cost: $1000s
Operating system: UNIX, DOS
Platforms: PC, workstation
Structure: Topological vector with raster
Analysis: T,T,T,T,T,T

Name: SPANS
Company: TYDAC Technologies Corp.
Cost: $1000s
Operating system: UNIX, OS/2
Platforms: PC, workstation
Structure: Raster/Quadtree
Analysis: T,T,T,T,T,T

Name: System 9
Company: Computervision
Cost: $10,000s
Operating system: UNIX
Platforms: Workstation
Structure: Topological vector
Analysis: T,T,T,T,T,F

Name: GIS Plus
Company: Caliper Corp.

Cost: $1,000s
Operating system: DOS
Platforms: PC
Structure: Topological vector
Analysis: T,F,F,T,T,F

Name: MapGrafix
Company: ComGrafix, Inc.
Cost: $1,000s
Operating system: Mac
Platforms: Mac
Structure: Nontopological vector
Analysis: T,F,T,F,T,F

Name: MapBox
Company: Decision Images, Inc.
Cost: $100s
Operating system: UNIX, DOS
Platforms: PC, workstation
Structure: Raster
Analysis: T,T,T,T,F,F

Name: TerraSoft
Company: Digital Resource Systems, Ltd.
Cost: $10,000+
Operating system: UNIX, DOS
Platforms: PC, workstation
Structure: Raster
Analysis: T,T,T,F,T,F

Name: GENAMAP
Company: Genasys II, Inc.
Cost: na
Operating system: UNIX
Platforms: PC, workstation
Structure: Topological vector
Analysis: T,T,T,T,T,F

Name: GeoVision's GIS
Company: GeoVision Systems Inc.
Cost: na
Operating system: UNIX, VMS
Platforms: workstation, mini
Structure: Topological vector
Analysis: T,T,T,T,T,F

Name: Graphics Design System (GDS)
Company: McDonnell Douglas
Cost: $10,000+
Operating system: VMS
Platforms: workstation
Structure: Topological vector
Analysis: T,T,T,T,T,F

Name: MIPS
Company: MicroImages, Inc.

Cost: $1 [illegible]
Operating system: DOS
Platforms: PC
Structure: Raster
Analysis: T,T,T,T,T,T

Name: PMAP
Company: Spatial Information Systems
Cost: $100s
Operating system: DOS
Platforms: PC
Structure: Raster
Analysis: T,T,T,T,T,F

Name: INFORMAP
Company: Synercom Technology, Inc.
Cost: na
Operating system: UNIX, VMS
Platforms: PC, Mac, workstation
Structure: Topological vector
Analysis: T,T,T,T,T,F

Name: MicroImage
Company: Terra-Mar Resource Information
Cost: $1,000s
Operating system: DOS
Platforms: PC
Structure: Raster
Analysis: T,T,T,F,T,T

Name: MacGIS
Company: University of Oregon
Cost: $100s
Operating system: Mac
Platforms: Mac
Structure: Raster
Analysis: T,T,T,T,F,F

APPENDIX II. REFERENCES

Aller, L., Truman, B., Lehr, J. H., Petty, R. J., and Hackett, G. (1987). "DRASTIC: A standardized system for evaluating ground water pollution potential using hydrogeologic settings." *EPA publication 600/2-87-035*, Robert S. Kerr Environmental Research Laboratory, Environmental Protection Agency, Ada, Okla.

Armstrong, D. H. (1991). "Scanning: An alternative means of spatial database construction." *GIS applications in natural resources*, M. Heit and A. Shortried, eds., GIS World, Inc., Fort Collins, Colo.

Baffles, A., Nagel, D., Bozeman, J., Ambrose, J., and Raboli, C. (1990). "Reservoir site assessment using remotely sensed imagery and GIS: A case study of the West Georgia regional reservoir project." *Proc., GIS/LIS '90*, American Congress on Surveying and Mapping, Falls Church, Va., 762–765.

Burrough, P. A. (1986). *Principles of geographical information systems for land resource assessment.* Oxford University Press, Oxford, England.

Couch, D. (1991). "GIS—Is it cost-effective: A case study." *GIS applications in natural resources*, M. Height and A. Shortried, eds., GIS World, Inc., Fort Collins, Colo.

Cowden, R. W. (1991). "Stormwater/wastewater management: How an application can drive a GIS." *Proc., ASCE Water Resour. Planning and* [illegible]*nd Urban Water Resour. 18th Annual Conf. and Sympos.*, ASCE, New Y[illegible]N.Y., 913–917.

Cowen, D. J. (1990). "GIS versus CAD versus DBMS: What are the differences?" *Introductory readings in geographic information systems*, D. J. Peuquent and D. F. Marble, eds., Taylor & Francis, London, England.

De Man, W. H. E. (1988). "Establishing a geographical information system in relation to its use: A process of strategic choices." *Int. J. Geographic Information Systems*, 2, 245–261.

Dickinson, H. J., and Calkins, H. W. (1988). "The economic evaluation of implementing a GIS." *Int. J. Geographic Information Systems*, 2(4), 307–327.

Epstein, E. F., and Roitman, H. (1990). "Liability for information." *Introductory readings in geographic information systems*, D. J. Peuquent and D. F. Marble, eds., Taylor & Francis, London, England.

Evans, B. M., and Myers, W. L. (1986). *Computer analysis of multiple layers of spatially oriented environmental data for evaluating potential groundwater impacts.* Pennsylvania State University Publications, University Park, Pa.

Geographic information 1991; Yearbook of the association for geographic information. (1991). J. Cadoux-Hudson and D. I. Heywood, eds., Taylor & Francis, London, England.

Geographic information systems for resource management: A compendium. (1989). W. J. Ripple, ed., American Congress on Surveying and Mapping and American Society for Photogrammetry and Remote Sensing, Falls Church, Va.

"Geographic information systems: Training recommendations." (1989). *Administration and Resourc. Mgmt. Rep. PM-218B*, United States Environmental Protection Agency, Washington, D.C.

GIS applications in natural resources. (1991). M. Heit and A. Shortried, eds., GIS World, Inc., Fort Collins, Colo.

Grayman, W. M., Finkeldey, J., Goodrich, J. A., and Heath, J. (1991). "Integration of GIS and water quality modeling in the Ohio River Basin." *Proc., 1st Int. Conf./Workshop on Integrating GIS and Envir. Modeling*, National Center for Geographic Information and Analysis, University of California, Santa Barbara, Calif.

Goodchild, M. F., and Gopal, S. (1989). *The accuracy of spatial databases.* Taylor & Francis, London, England.

Goodchild, M. F., and Rizzo, B. R. (1987). "Performance evaluation and workload estimation for GIS." *Int. J. Geographic Information Systems*, 1(1), 67–76.

Hazelton, N. W. J., Leahy, F. J., Williamson, I. P. (1990). "On the design of temporally-referenced, 3-D GIS: Development of four-dimensional GIS." *GIS/LIS '90: Proc., GIS/LIS Annual Conf.*, Anaheim, Calif., Vol. 1, 357–373.

Howard, D. C., and Barr, C. J. (1991). "Sampling the countryside of Great Britain: GIS for the detection and prediction of rural change." *GIS applications in natural resources*, M. Heit and A. Shortried, eds., GIS World, Inc., Fort Collins, Colo.

Intelligent infrastructure workbook: A management level primer in GIS. (1990). E. Forrest, ed., AEC Automation Newsletter, Fountain Hills, Ariz.

Introductory readings in geographic information systems. (1990). D. J. Peuquent and D. F. Marble, eds., Taylor & Francis, London, England.

Leipnik, M. R., and Loaiciga, H. A. (1991). "Use of GIS in the study of water resources." *Proc., ASCE Water Resour. Planning and Mgmt. and Urban Water Resour. 18th Annual Conf. and Symp.*, ASCE, New York, N.Y. 887–892.

Maguire, D. J., Goodchild, M. F., and Rhind, D. W. (1991). *Geographical information systems: Principles and applications.* Longmans, London, England.

Marble, D. F., and Sen, L. (1986). "The development of standardized benchmarks for spatial database systems." *Proc., 2nd Int. Symp. on Spatial Data Handling*, International Geographical Union, Commission on Geographical Data Sensing and Processing, Williamsville, N.Y.

Marshall, E. J., Segerson, J. A., Siburg, D. R., and Jones, D. M. (1990). "Interagency water database coordination case study: Kitsap County public utility district's data management system." *GIS/LIS 1990: Proc., 1990 GIS/LIS Annual Conf.*, Anaheim, Calif.

Michael, E[illegible]). *The environmental resource management and assessment system white pa*[illegible]tergraph Corp., Huntsville, Ala.

Mitsova, H., and Iverson, L. R. (1991). "Study of environmental impact of proposed water reservoir using GIS and improved methods of topographic analysis." *Proc., 1st Int. Conf./Workshop on Integrating GIS and Envir. Modeling*, National Center for Geographic Information and Analysis (NCGIA), University of California, Santa Barbara, Calif.

NCGIA core curriculum in GIS. (1990). M. F. Goodchild and K. K. Kemp, eds., National Center for Geographic Information and Analysis (NCGIA), University of California, Santa Barbara, Calif.

1991–1992 international GIS sourcebook. (1991). H. D. Parker, ed., GIS World Magazine, Fort Collins, Colo.

Reed, E. O. (1991). "Using a distributed GIS data-base in forest planning." *GIS applications in natural resources*, M. Heit and A. Shortried, eds., GIS World, Inc., Fort Collins, Colo.

Star, J. L., and Estes, J., (1990). *Geographic information systems: An introduction*. Prentice-Hall, Englewood Cliffs, N.J.

Teorey, T. J. (1990). *Database modeling and design: The entity-relationship approach*. Morgan Kaufmann, San Mateo, Calif.

Three dimensional applications in geographic information systems. (1989). J. Raper, ed., Taylor & Francis, London, England.

U.S. GeoData: Catalog of digital data. (1991). National Mapping Program, United States Geologic Survey (USGS), Reston, Va.

Webster-Scholten, C. P. (1990). "Environmental restoration: Dynamic planning and innovation." *Energy and technology review*, Lawerence-Livermore National Laboratory, Livermore, Calif., 18–24.

Weibel, R., and Heller, M. (1991). *Geographical information systems: Principles and applications*. D. J. Maguire, M. F. Goodchild, and D. W. Rhind, eds., Longmans, London, England.

Wright, W. R., and Buehler, K. T. (1989). *GIS: A proving ground for water resource management research*. Purdue University, West Lafayette, Ind.

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Use of the Cone Penetration Test and BAT Groundwater Monitoring System to Assess Deficiencies in Monitoring Well Data

Nicholas A. Berzins
The Earth Technology Corporation
Huntington Beach, California

ABSTRACT

Improperly planned or constructed monitoring wells lead to inaccurate assessments of piezometric levels, hydraulic gradients and groundwater chemistry. In situ testing and sampling techniques, including the Cone Penetration Test (CPT) and the BAT Groundwater Monitoring System, provide high resolution stratigraphic and hydrogeologic data and depth discrete sampling capabilities which are effectively used to optimize the number and location of wells required for effective site assessment and monitoring. These techniques are used to define deficiencies in drilling and sampling programs on sites where existing boreholes and monitoring wells yield inconsistent or inconclusive stratigraphic, piezometric level and groundwater chemistry data.

A common approach to site assessments is to conduct a drilling program utilizing soil sampling at preset intervals, generally 5 or 10 feet. Based on the onsite interpretations of stratigraphy and moisture content a monitoring well is constructed, in most cases completed over an interval spanning 5 feet above to 15 feet below the apparent water level. Deficiencies inherent in this system include the potential to miss soil type changes between sampling points, the potential to interconnect distinct aquifer or hydrogeological zones, and the inconsistencies in visually defining soil characteristics.

The cone penetration test (CPT) utilizes a cone-tipped cylindrical probe which continuously measures the soil resistance to penetration as well as pore water pressures. The piezocone is advanced into the ground by hydraulic rams mounted on a heavily weighted (20 ton) truck. Onsite computer processing of piezocone measurements provides stratigraphic profiles indicating presence of saturated zones and variations in permeability. The rig is also used to deploy depth-discrete groundwater sampling probes which target saturated zones as thin as 4 inches in thickness.

The CPT and BAT Groundwater Monitoring System were utilized on two field investigations to interpret existing borehole and monitoring well data. Stratigraphic profiles obtained from the CPT indicated that monitoring wells were completed across distinct hydrogeological zones, yielding inaccurate piezometric level data. Depth-discrete groundwater sampling utilizing the BAT system confirmed that monitoring well groundwater chemistry data was also inaccurate, reflecting a composite value from zones of high and low to non-detected contamination.

INTRODUCTION

The ability to accurately define geological and hydrogeological conditions and to accurately define the presence and migration of contaminants are the foundation for all site assessment and remediation programs. However, site assessments are commonly approached by conducting drilling programs utilizing soil sampling at preset intervals. The resulting generalized stratigraphy is used to construct monitoring wells. In many cases this program is conducted by the least experienced member of the engineering team. The deficiencies inherent in this system include:

- the potential to miss changes in soil type between sampling points;
- inconsistencies inherent in visually classifying soil types and moisture contents;

- the potential to interconnect hydrogeologically distinct zones resulting in inaccurate measurements of water levels, hydraulic gradients and groundwater chemistry, as well as providing a potential for contaminant migration by creating artificial pathways;
- the potential to create inaccurate assessments of extent of contamination, particularly extent of free product, from monitoring wells completed over excessively broad intervals and subjected to excessive drawdown during development and sampling.

This paper presents two techniques which are utilized to obtain continuous high resolution geological and hydrogeological data and to collect depth discrete water samples. These techniques, the Cone Penetration Test (CPT) and the BAT Groundwater Monitoring System (BAT), are used to assess deficiencies in current monitoring well programs and to optimize future drilling and monitoring well installation programs. The use of these techniques on two field investigations is presented.

THE CONE PENETRATION TEST

The CPT is used to provide a continuous stratigraphic profile, including delineating the presence of permeable and impermeable layers; to assess depth to groundwater and to assess soil permeability. This technique is applicable in gravelly sands or finer-grained soils and typically limited to depths of 125 feet.

The Cone Penetration Test (CPT), governed by ASTM Standard D3441-86, is performed by pushing a cone-tipped cylindrical probe, referred to as a piezocone, into the ground while continuously recording the resulting resistance to penetration, dynamic pore pressure and inclination. The piezocone is attached to, and advanced at a constant rate of 2 cm/sec using, successive lengths of 1 meter long steel pipe. The reaction force required to deploy the piezocone is supplied by hydraulic rams mounted inside the van compartment of a 20 ton vehicle (Figure 1-A). The process of advancing the piezocone is referred to as a sounding.

The piezocone (Figure 1-B) contains strain-gauged load cells, a pressure transducer and an accelerometer, which are used to record independent measurements of: soil bearing resistance (Q_c) acting on the conical tip; soil shearing resistance (F_s) acting along the cylindrical friction sleeve; dynamic pore pressure (u) and probe inclination. These measurements are recorded continuously versus depth and transmitted via cable to a PC-based data acquisition system mounted inside the van. These data are displayed on a monitor as the test is conducted and are printed, along with calculated parameters, the friction ratio ($^{F}s/_{Qc}$) and pore pressure ratio ($^{u}/_{Qc}$), upon completion of the test (Figure 2a-e).

Penetration of the piezocone is temporarily stopped at selected depths to allow monitoring of pore water pressure versus time. Information obtained from this test, referred to as a pore pressure dissipation test (PPDT), is used to assess depth to groundwater and to assess permeability. Dynamic pore pressure, "excess" pressures generated by the penetration-induced stresses in the soil, decrease or dissipate over time and approach a static or equilibrium pressure. Graphs of the dissipation test are plotted upon completion of the sounding (Figure 3).

Practical application of the CPT data involves onsite, computerized, interpretation of the basic data. A computerized database, containing laboratory and field correlations, is utilized to generate plots of soil behavior type versus depth (Figure 2f). The generalized trend in the correlation reflects that in cohesive soils the larger component of resistance will be due to soil shearing resistance, therefore lower Q_c values and higher friction ratio values, while in non-cohesive soils the larger component of resistance will be due to soil bearing resistance, therefore higher Q_c values and lower friction ratio values.

Visual observation of the pore pressure data refines the soil behavior type interpretation, and is used to assess the presence of groundwater, and permeable and impermeable layers. Each moisture bearing zone is identified by a positive pore pressure measurement. Clays, low permeability soils, are characterized by high excess pore pressures and slow pore pressure dissipation compared to sands, higher permeability

soils, which exhibit minimum excess pore pressures (Figure 2d and 2f) accompanied by relatively rapid dissipation. The pore pressure response provides a higher resolution in assessing soil types since measurements are made in the immediate area of the piezocone tip compared to soil bearing resistance measurements, which are affected by the strength parameters of soils located behind and ahead of the piezocone tip.

Interpretation of the PPDT data yields depth to groundwater and permeability values. Depth to groundwater is calculated by subtracting the projected equilibrium pressure value from the value of the known depth of the piezocone. Horizontal permeability is calculated using the pore pressure dissipation curve and empirical correlations between permeability and soil compressibility and consolidation behavior (Hekma et al., 1990).

The typical sequence of events for utilizing the CPT as part of an investigation program involves:

- Performing a CPT sounding to anticipated exploration depth;
- Performing PPDT at selected depths if depth to groundwater is unknown;
- Performing interpretation of CPT data to derive soil behavior types;
- Calculating depth to groundwater and relative permeability from dynamic pore pressure data and PPDT;
- Determining sample depth, multiple depths if aquifer is non-homogeneous, while optimizing sampling time by selecting relatively permeable zones; and
- Deploying groundwater sampling probes, including the BAT Groundwater Monitoring System.

The initial CPT sounding may be performed adjacent to an existing "control point", for example an existing borehole or monitoring well. The comparison between the CPT data and the "control" data provides additional site specific correlations. Site specific correlations performed in this manner may permit extrapolation of textural definitions, for example those derived from the Unified Soil Classification System (USCS), from CPT soundings performed away from or between control points.

BAT GROUNDWATER MONITORING SYSTEM

The BAT Groundwater Monitoring System is used to collect depth discrete groundwater samples. The main components of the system (Figure 4) are:

- a cone-tipped filter tip used to access pore fluids at a specific depth;
- casing used to deploy the filter tip to the desired depth and to provide access to the filter tip from ground level;
- a deployment mechanism used to advance the filter tip to the desired depth; and
- kits which are lowered down the center of the casing and used to obtain groundwater samples, pore pressure measurements or permeability data from the filter tip.

The filter tip consists of a stainless steel porous filter area, approximately one inch in diameter and four inches in length, sealed at the top with a flexible rubber disc or septum, analogous to placing an impermeable membrane immediately above the screened portion of a monitoring well. The filter area, and all surfaces which will contact the sample are sealed by a retractable steel sleeve during penetration and are exposed only at the desired sampling depth. The filter tip is advanced directly from ground level by the hydraulic rams in the CPT rig using high strength, steel casing, each section 1m in length.

The sampling kit, which is lowered down the casing, consists of:

- a double-ended hypodermic needle, mounted inside a cylindrical carrier;
- a pre-evacuated, septum-sealed glass sample vial, ranging in size from 35 to 150 ml, contained inside a protective cylinder; and
- a weight chain and wire cable.

The key component in the assembly is the spring-loaded, double-ended hypodermic needle which allows a temporary, direct hydraulic connection between the fluids in the filter tip and the pre-evacuated sample vial. This needle assembly allows the sample vial to be lowered and raised in the extension pipe in a hermetically sealed state. The vial remains in this sealed condition until the sampler reaches the filter tip and the needle temporarily punctures the septa to form the connection between the filter tip and the vial. Samples obtained with this system are retained under insitu pressure and are submitted directly to the laboratory for analysis without exposure to ambient atmosphere and without rehandling into alternate containers. Additional measurement capabilities are available by utilizing a pore pressure transducer assembly in place of, or in conjunction with, the sample vial assembly. The ability of this technique to accurately obtain groundwater samples for volatile organic compounds (VOC's) has been verified during controlled testing (Blegen et al., 1988).

FIELD INVESTIGATION #1

The CPT and BAT techniques were deployed in March, 1991 on a site located in San Joaquin County, California. The site is an active service station, retailing regular, unleaded and super-unleaded gasoline. Previous site investigations, conducted to assess potential leakage from storage tanks and associated distribution lines, included removal and replacement of existing gasoline and waste oil storage tanks and installation of 5 monitoring wells (MW1 through MW5) with completion intervals ranging from approximately 6 to 32 feet below ground level. The stratigraphy within the depth of interest, based on prior investigations utilizing hollow stem auger and 5 foot sample intervals, consists of sand, silt and clay with an apparent groundwater table located at approximately 19 feet below ground level.

The initial objectives of the investigation were:

- o demonstrate the ability of the CPT to characterize the site geology and hydrogeology, and
- o assess the vertical distribution of petroleum hydrocarbons in the groundwater, specifically the adequacy of the monitoring wells to accurately represent this distribution.

In conjunction with this investigation, monitoring wells onsite were sampled and groundwater levels measured according to standard protocol.

Cone Penetration Tests were conducted adjacent to each monitoring well to maximum depths of approximately 31 feet below ground level. Pore pressure dissipation tests were conducted at a minimum of one depth during each sounding. Soil behavior types, interpreted from the CPT data, were utilized to select a BAT sampling depth at each location. BAT systems (B1 through B5) were installed to a maximum depth of approximately 25 feet below ground level and sampled at each location. The samples, along with samples from the corresponding monitoring wells were submitted for analysis using EPA Method 602 for: benzene; toluene; ethyl benzene; chlorobenzene; 1-4, 1-3 and 1,2-dichlorobenzene; and xylene. Monitoring well MW-1, CPT-1 and BAT B1, discussed in the following text, are located within 40 feet downgradient of the potential source.

Results and Analysis

The groundwater samples obtained from the BAT sampling probes indicated that samples from the monitoring wells did not accurately represent the vertical distribution of the analyte petroleum hydrocarbons. Concentrations at the BAT depth discrete intervals were generally 1% to 9% of the concentrations obtained from the corresponding monitoring wells.

These results mandated a review and assessment of BAT sampling intervals versus completion intervals of corresponding monitoring wells including a comparison between the geological and hydrogeological data provided by the CPT versus that provided by the previous drilling programs.

Data from the borehole lithology and monitoring well construction diagram were plotted (Figure 5) adjacent to data obtained from CPT-1. The corresponding sample interval from BAT B1 is also presented on this plot. Dissipation tests performed in CPT-1 were insufficient in duration to provide depth to groundwater information. Therefore, depth to groundwater obtained from dissipation tests in CPT-3, CPT-4 and CPT-5 are extrapolated onto the plot.

The geologic data obtained from the CPT correlates with the generalized borehole lithology, however, because the data are obtained continuously versus depth, the CPT provides better definition of changes in lithology than that provided by sampling at 5 foot intervals.

Piezometric data obtained from the pore pressure dissipation test conducted in CPT 3 correlated with depth to groundwater obtained from the monitoring well. However, dissipation tests conducted in CPT 4 and CPT 5, at greater depths, contained anomalies in piezometric data compared to the depth to water in MW-1 and the general depth to groundwater across the site. These anomalies, beyond the range of inaccuracies in the measurement system, are believed to be due to the depth discrete measurement of the piezocone versus the "composite" level provided by the relatively broad completion interval of the monitoring well. These measurements would indicate that the monitoring well may be completed across more than one distinct hydrogeological zone.

The BAT B1 sampling interval is a 4 inch long filter area located at a depth of approximately 24 feet below ground level. The MW-1 completion interval is effectively 26 feet, ranging from 6 feet to 32 feet below ground level. The broad completion interval of the monitoring well, with a screened section at a very shallow depth in close proximity to the potential source, may intercept and collect either unsaturated or perched lateral contaminant migration or saturated zone contaminant migration. The depth discrete BAT sample indicates that the distribution of the hydrocarbons may be primarily lateral rather than vertical and that the well may be completed across more than one district hydrogeological zone. Therefore, in addition to providing "composite" piezometric levels, the monitoring wells may provide "composite" groundwater chemistry values and in certain cases may tend to overestimate, because of the broad sampling interval, the extent of groundwater contamination. At the time of publication a second phase of investigation, utilizing BAT samples over multiple depths adjacent to the monitoring well completion intervals, is being proposed.

FIELD INVESTIGATION #2

The CPT and BAT techniques were deployed in September 1991 on a site located in Los Angeles County, California. The site is an active transit facility utilizing underground diesel, unleaded gasoline, motor oil, waste oil and solvent tanks. Previous site investigations conducted to assess potential leakage from storage tanks and associated distribution lines, included installation of groundwater monitoring wells. The stratigraphy within the depth of interest, based on drilling conducted with hollow stem augers and 5 foot sample intervals, consists of a veneer of fill underlain by alluvial fan deposits of clay, silt and sands. The general depth to groundwater is approximately nine feet below ground level.

The initial objective of the program was to assess the accuracy of the monitoring wells for defining vertical and lateral distribution of hydrocarbons and to conduct screening, utilizing the BAT system, across the site. In conjunction with this investigation, monitoring wells onsite were sampled and groundwater levels measured according to standard protocol. For brevity, the presentation of data is restricted to discussion of only a limited portion of the field program.

Cone Penetration Tests were conducted to maximum depths of approximately 25 feet below ground level primarily to aid in effective placement of the BAT filter tips. Pore pressure dissipation tests were conducted at selected depth intervals. A total of 11 CPT soundings were performed with a corresponding installation and sampling or attempted sampling of 11 BAT filter tips. BAT groundwater samples were submitted for analysis using EPA Method 8015 Modified. This presentation focusses on the results from one CPT sounding and BAT sample location (CPT-11A and BAT 11A) and one adjacent monitoring well location (MW-6), all located within 100 feet downgradient of the potential source.

Results and Analysis

Monitoring well MW-6 contained free diesel product and high concentrations of dissolved total petroleum hydrocarbons. Samples obtained from BAT B11A were non-detect for these analytes. A comparison of the geology and sampling intervals between CPT-11A, BAT 11A and MW-6 is presented in the following text.

Information from CPT-11A was plotted adjacent to the borehole log and monitoring well construction diagram for MW-6. The sample interval for BAT11A is also presented on this figure (Figure 6).

The CPT data indicate that the borehole lithology presents an oversimplified description of the stratigraphy. Visual classification of the soils at the sample intervals appears reasonable, however, significant changes in soil type occur between sample points. The borehole log classifies soils as clayey sand, which on the CPT log vary from clay to sand. While the CPT interpretations reflect 'soil behavior types' not definitive soil types, the CPT does indicate distinct changes in soil type over this interval.

The pore pressure dissipation test conducted at a depth of 21 feet indicated a depth to water of approximately 12 feet below ground level compared to a measurement of 9.35 feet below ground level in MW-6. The CPT measurement reflects a depth discrete measurement while the well is completed over an interval of approximately 18 feet. MW-6 may intersect distinct hydrogeological zones including possible localized perched zones. Potential perched conditions are indicated by the positive dynamic pore pressure response to depths of 12 feet below ground level.

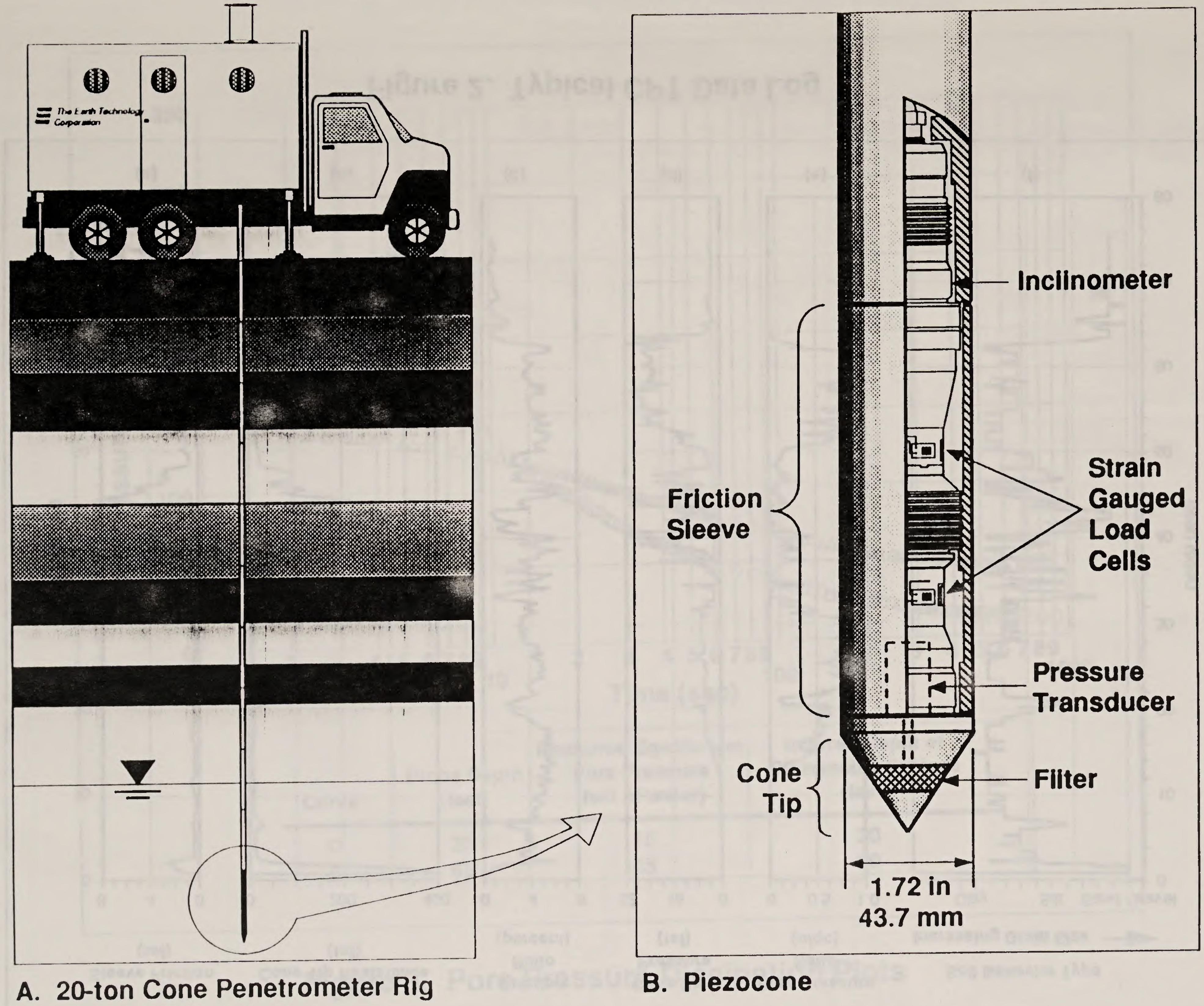
The variation between the analytical results between BAT B11A and MW-6 appears to be a result of the difference in completion intervals. Movement of contaminants may be through lateral unsaturated or perched layer migration or through a thin saturated layer intersected by the monitoring well. The BAT sample indicates that the movement of the petroleum hydrocarbons may be primarily lateral and more limited in vertical extent than indicated by the monitoring well. At the time of this publication a second phase of investigation, utilizing the BAT sample over multiple depths is proposed. This second phase will also assess the potential for the 'near surface' completion interval of the well to act as a collector of petroleum hydrocarbons which have not yet migrated vertically downward into the groundwater.

CONCLUSIONS

CPT soundings were used to assess the geological and hydrogeological data provided by current borehole drilling and monitoring well construction techniques. The results indicated that the CPT, due to its ability to provide high resolution data and depth discrete measurement of hydrostatic pressures and relative permeability, is an effective tool for environmental site assessments conducted in gravelly sands or finer-grained soils to maximum depths of 125 feet. In areas not conducive to CPT, continuous coring techniques at a representative number of locations and visual classification, supplemented by selected index property testing are recommended.

The BAT technique was used to assess the depth discrete groundwater chemistry in areas where monitoring wells, with broad completion intervals, particularly those completed at very shallow depths in close proximity to the potential source, may provide inaccurate assessment of extent of contamination. The results indicated that depth discrete data provided by the BAT is required for effective location and construction of monitoring wells. When used as a screening technique depth discrete samplers, including the BAT, should be applied over multiple depths on sites where multiple groundwater flow paths may exist.

Data collected during these investigations, believed to be representative of a large cross section of current monitoring well and depth-discrete sampling programs, did not focus on the chemical properties of the specific contaminants and their impact on migration. However, these investigations do indicate a necessity to consider the chemical properties, including specific gravity and solubility, in addition to the site specific geological and hydrogeological conditions, when implementing monitoring well or depth discrete sampling techniques.



A. 20-ton Cone Penetrometer Rig

B. Piezocone

Figure 1. CPT Equipment

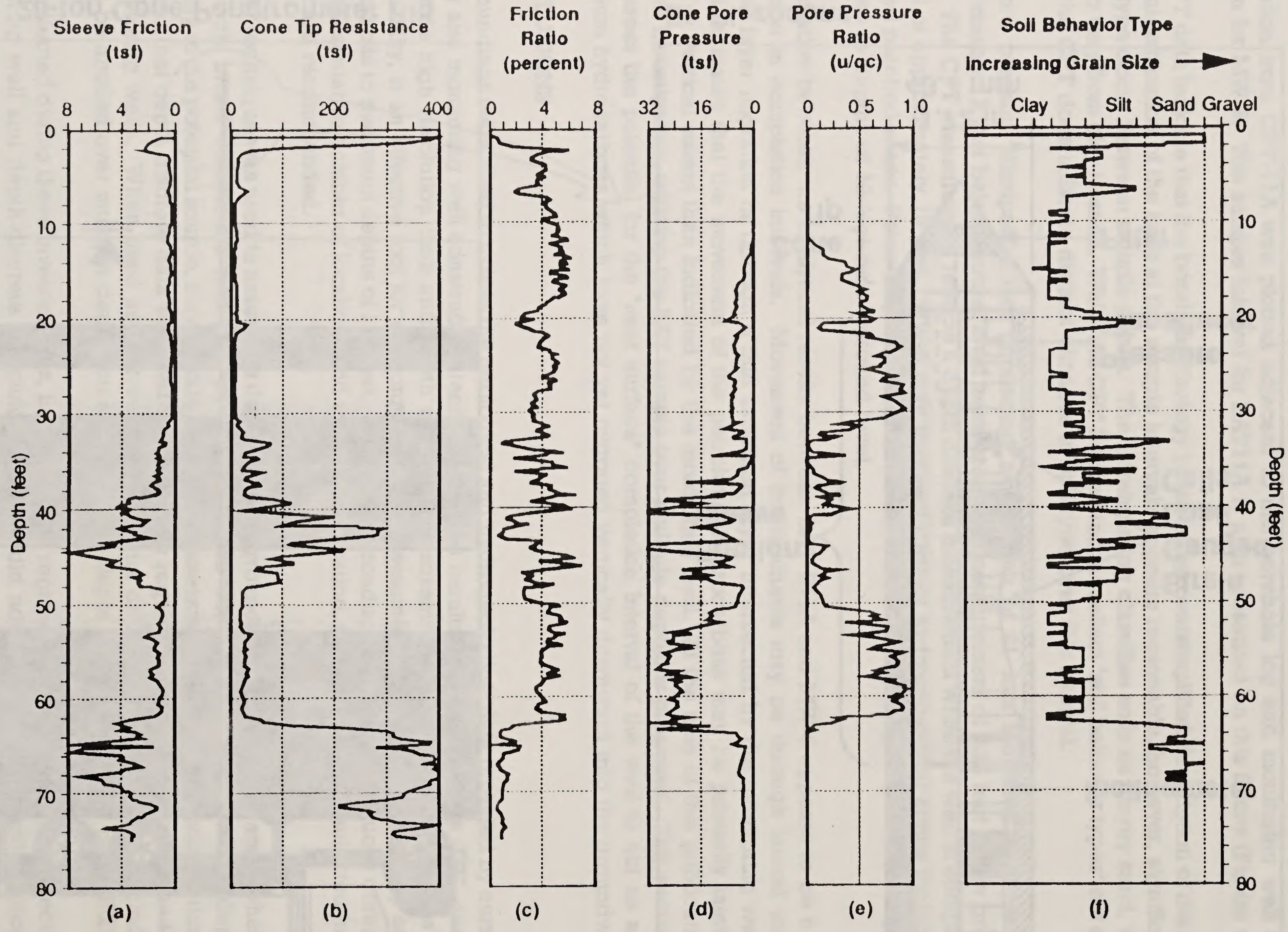
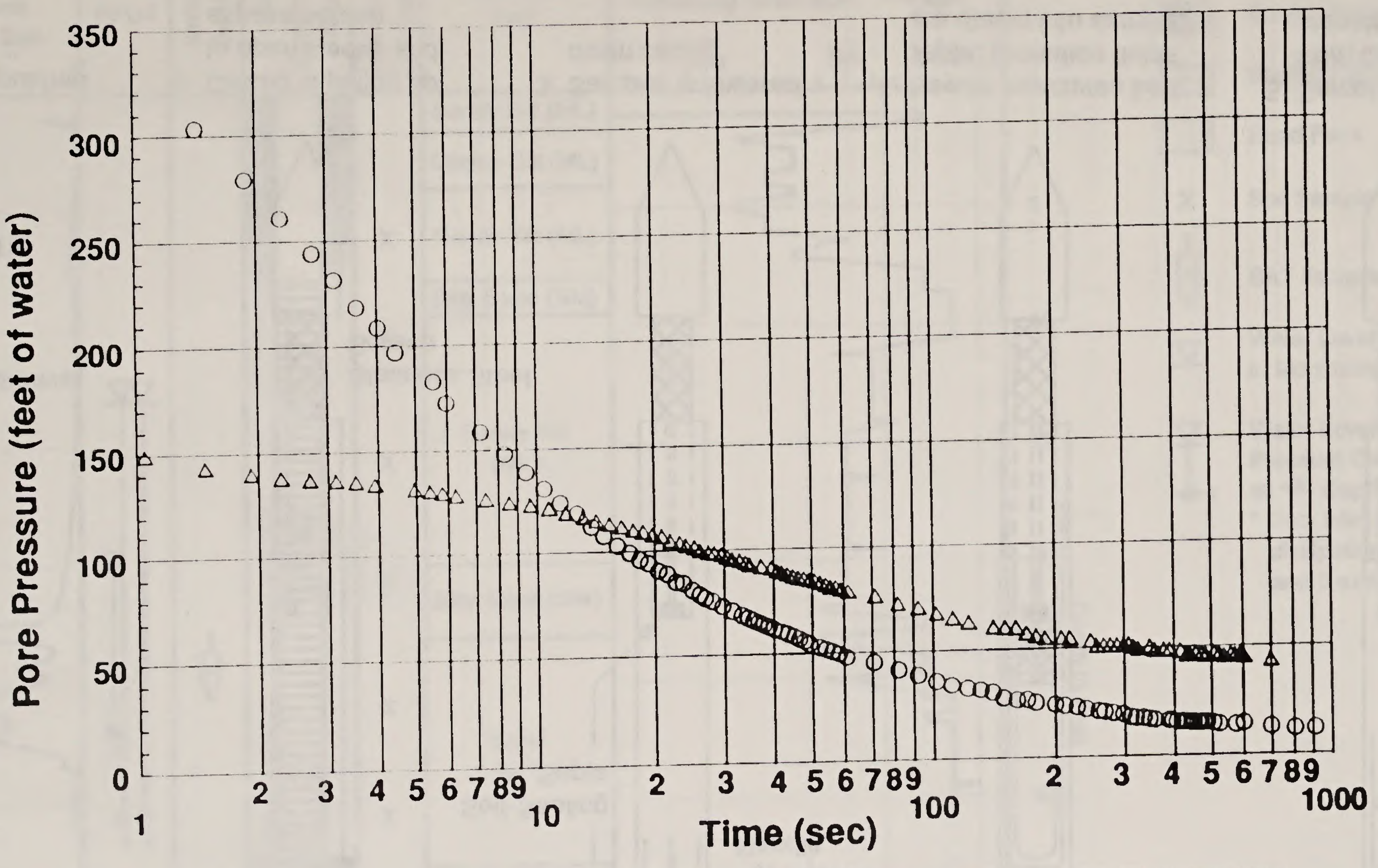
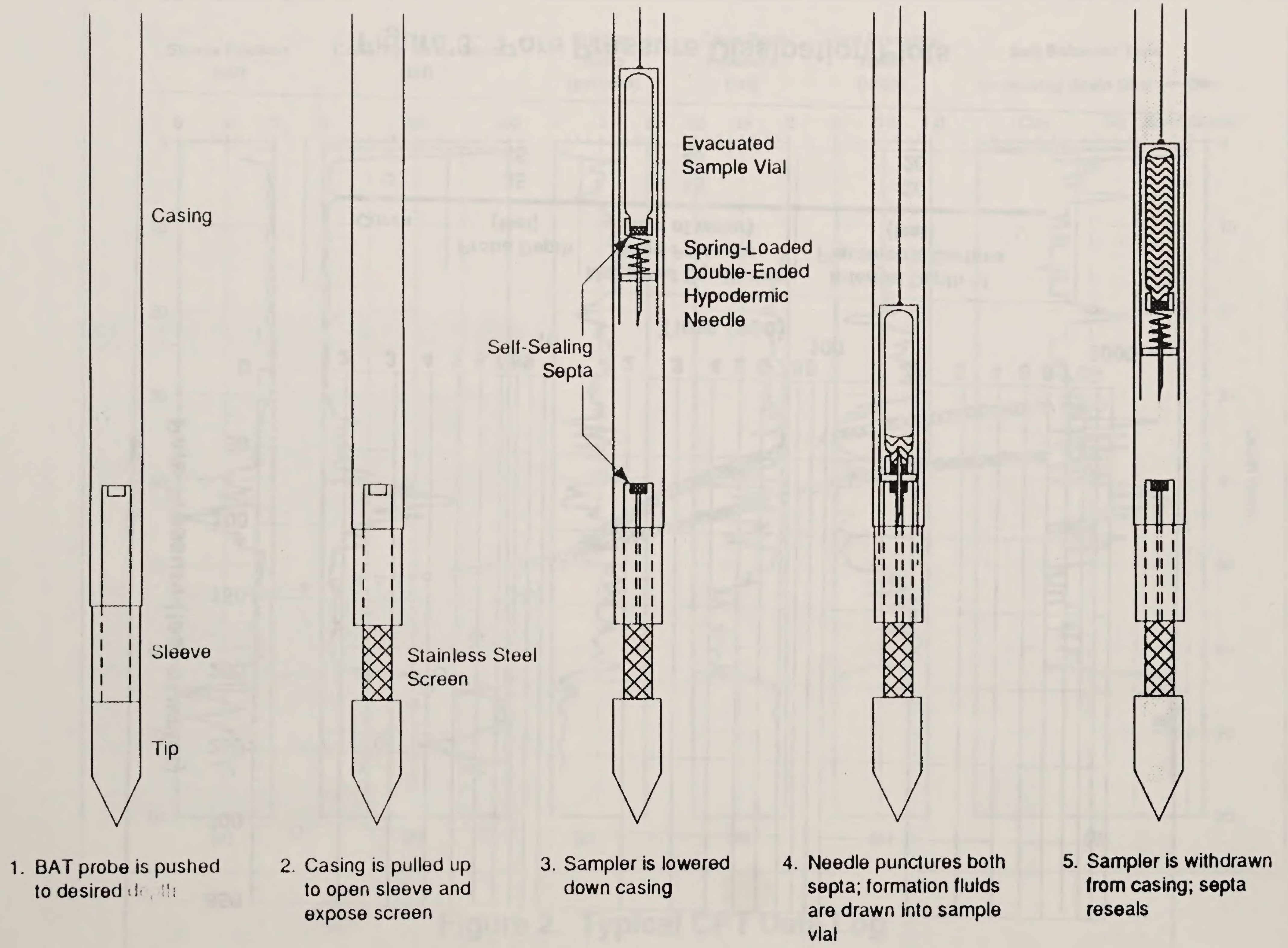


Figure 2. Typical CPT Data Log



Curve	Probe Depth (feet)	Measured Equilibrium Pore Pressure (feet of water)	Inferred Depth of Piezometric Surface (feet)
○	35	15	20
△	65	45	20

Figure 3. Pore Pressure Dissipation Plots



Casing
Sleeve
Tip
Stainless Steel Screen
Self-Sealing Septa
Evacuated Sample Vial
Spring-Loaded Double-Ended Hypodermic Needle
1. BAT probe is pushed to desired depth
2. Casing is pulled up to open sleeve and expose screen
3. Sampler is lowered down casing
4. Needle punctures both septa; formation fluids are drawn into sample vial
5. Sampler is withdrawn from casing; septa reseals

Figure 4. BAT® Groundwater Monitoring System

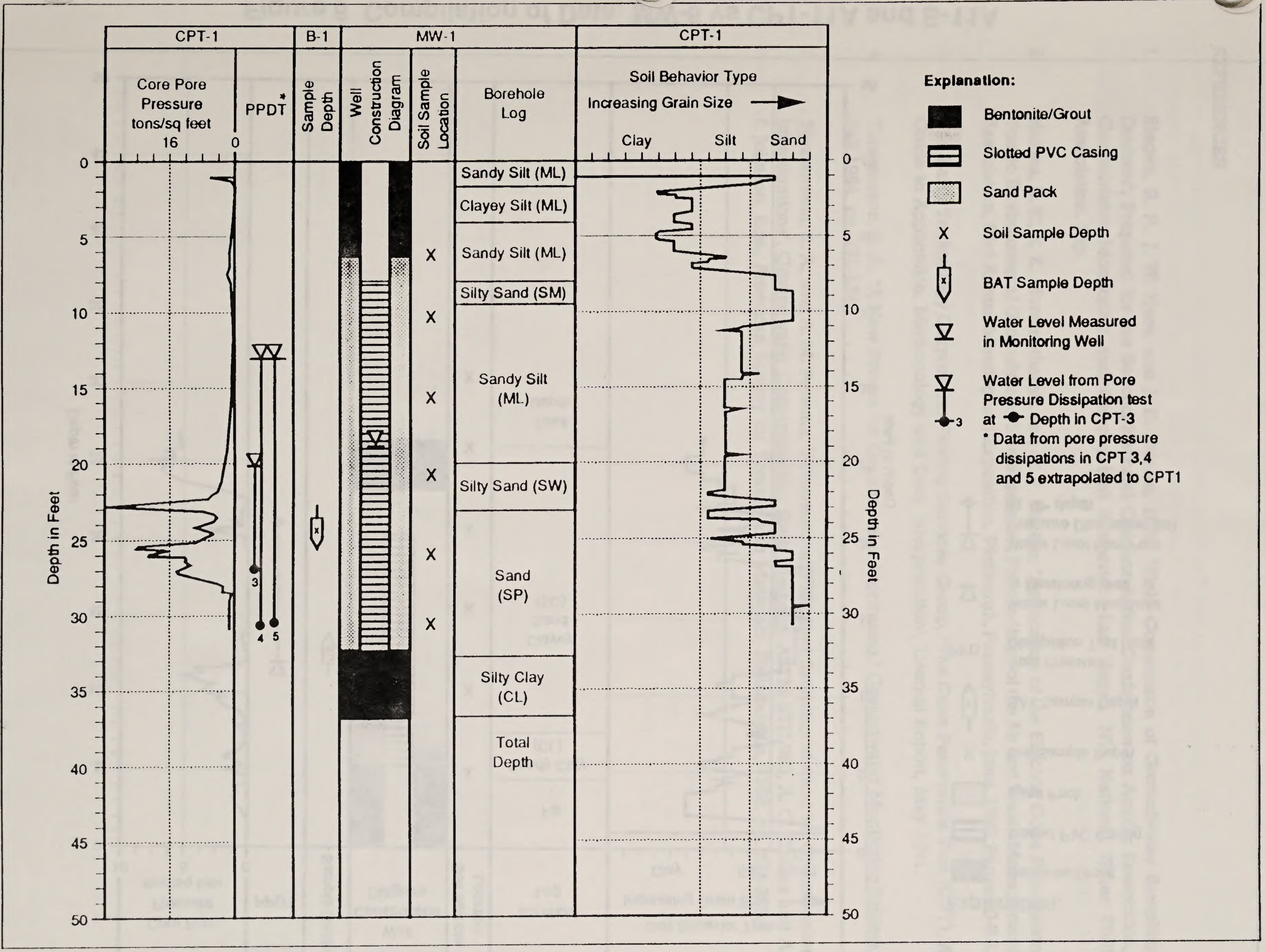


Figure 5 Compilation of Data, MW-1 vs CPT-1 and B-1

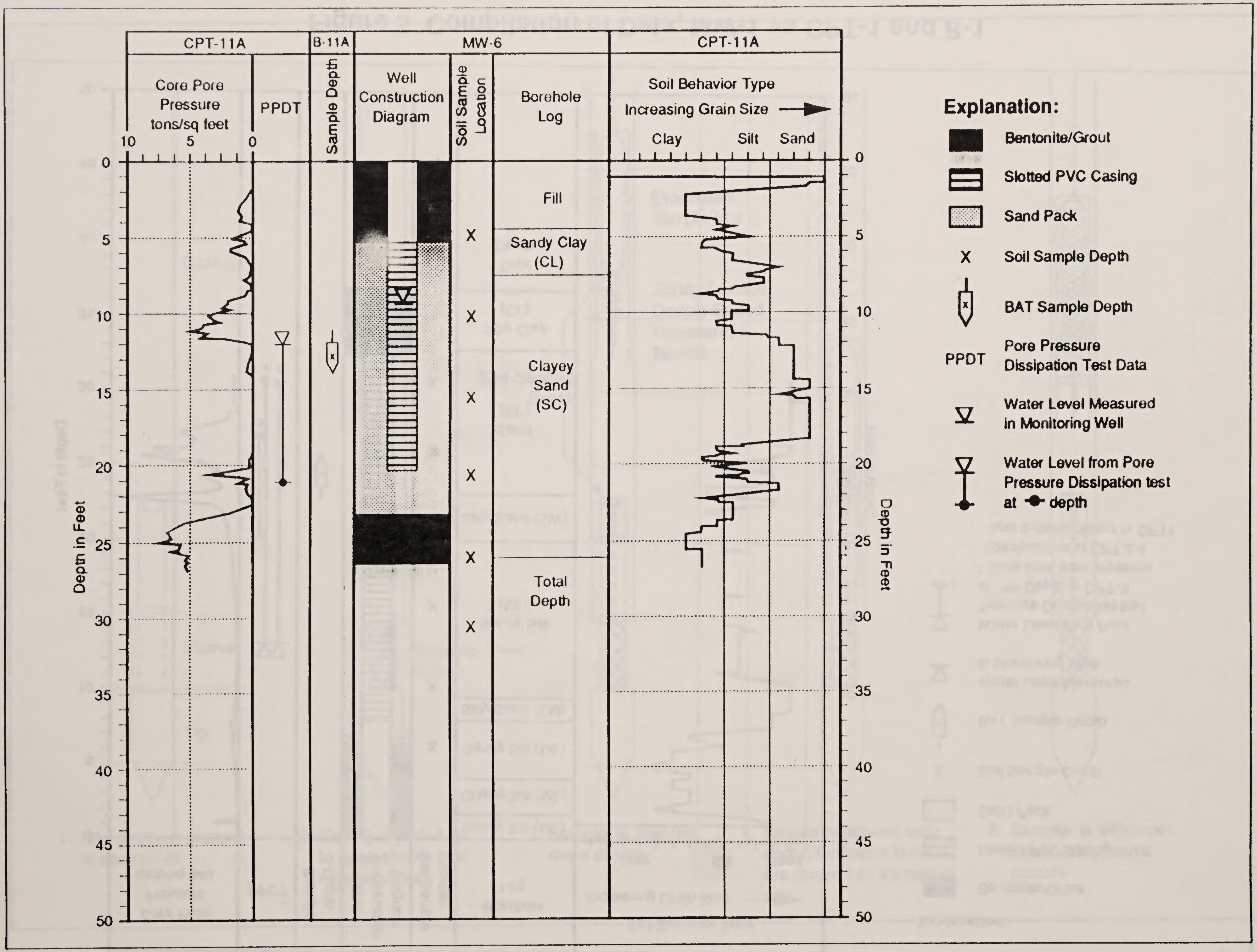


Figure 6 Compilation of Data, MW-6 vs CPT-11A and B-11A

REFERENCES

1. Blegen, R. P., J. W. Hess, and J. E. Denne, 1988, "Field Comparison of Groundwater Sampling Devices", Prepared for the Second National Outdoor Action Conference on Aquifer Restoration, Groundwater Monitoring and Geophysical Methods: Las Vegas, NV, National Water Well Association, 23p.

2. Hekma, L. K., K. K. Muraleetharan, and G. F. Boehm, "Application of the Electric Cone Penetration Test to Environmental Groundwater Investigations", Proceedings of the Air and Waste Management Association, 83rd Annual Meeting and Exposition, Pittsburgh, Pennsylvania, June, 1990, Pages 90-9.3.

3. The Earth Technology Corporation Testing Services Group, "The Cone Penetration Test (CPT), A Guide to Application, Methodology and Data Interpretation", Internal Report, May 1991.

4. Torstensson, B. A., "A New System for Groundwater Monitoring," Groundwater Monitoring Review, Fall 1984, pp. 131-138.

5. Torstensson, B. A., and A. M. Petsonk, "A Hermetically Isolated Sampling Method for Groundwater Investigations", Groundwater Contamination: Field Methods, ASTM STD 963, A. G. Collins and A. I. Johnson, Eds., American Society for Testing and Materials, Philadelphia, 1988, pp. 274-278.

Biographical Sketch

Nicholas Berzins is a Senior Engineer with The Earth Technology Corporation (TETC) in Huntington Beach, California. He received a B.A.Sc in Civil Engineering (1983) from the University of British Columbia in Vancouver, B.C., Canada. Prior to joining TETC he was President of BAT Envitech Inc., Huntington Beach, California. His experience and current responsibilities include development and implementation of in situ testing, including the Cone Penetration Test, and sampling techniques for environmental and geotechnical site assessments.

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UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

PROCEDURE FOR

USBR 7021-89

PERFORMING CONE PENETRATION TESTING OF SOILS — ELECTRICAL METHOD

INTRODUCTION

This procedure is under the jurisdiction of the Geotechnical Services Branch, code D-3760, Research and Laboratory Services Division, Denver Office, Denver, Colorado. The procedure is issued under the fixed designation USBR 7021. The number immediately following the designation indicates the year of acceptance or the year of last revision.

1. Scope

1.1 This designation outlines the procedure for determining the resistance to penetration of a conical pointed penetrometer as it is advanced into subsurface soils at a slow, steady rate.

1.2 This method can also be used to determine the frictional resistance of a cylindrical sleeve located behind the conical point as it is advanced through subsurface soils at a slow, steady rate.

1.3 This method includes the use of both cone and friction-cone penetrometers of the electrical type.

1.4 This method can be used to determine pore pressure development during push of a piezocone penetrometer. Pore pressure dissipation, after a push, can also be monitored for correlation to soil compressibility and permeability.

1.5 Cone penetration test data can be used to interpret subsurface stratigraphy, and through use of correlations it can provide data on engineering properties of soils intended for use in design and construction of earthworks and foundations for structures.

1.6 The test is limited to use in soils whose maximum particle size is less than approximately twice the cone diameter.

NOTE 1.–This method does not include hydraulic pneumatic penetrometers. However, many of the requirements herein could apply to those penetrometers.

2. Auxiliary Tests

2.1 When site-specific correlations are to be developed, cone penetration testing may be accompanied by standard penetration tests, undisturbed soil sampling, and vane shear tests performed in accordance with USBR 7015, 7105, and 7115, respectively.

3. Applicable Documents

3.1 *USBR Procedures*:
USBR 1040 Calibrating Pressure Gauges
USBR 1045 Calibrating Force Transducers (Load Cells)
USBR 1050 Calibrating Pressure Transducers
USBR 3900 Standard Definitions of Terms and Symbols Relating to Soil Mechanics
USBR 7015 Performing Penetration Resistance Testing and Sampling of Soil
USBR 7105 Performing Undisturbed Soil Sampling by Mechanical Drilling Methods
USBR 7115 Performing Field Vane Shear Testing

3.2 *ASTM Standard*:
E 4 Load Verfication of Testing Machines

3.3 *American National Standard*:
ANSI B46.1-1978 Surface Texture, Surface Roughness, Waviness and Lay, American Society of Mechanical Engineers

3.4 *USBR Document*:
Driller's Safety Manual

4. Summary of Method

4.1 A penetrometer tip with a conical point having a 60-degree apex angle and a cone base area of 10 or 15 cm^2 is advanced through the soil at a constant rate of 2 cm/s. The force on the conical point (cone) required to penetrate the soil is measured by electrical methods, a minimum of every 20 cm of penetration. Stress is calculated by dividing the measured force (total cone force) by the cone base area to obtain cone resistance, q_c.

4.2 If a friction sleeve is present on the penetrometer tip, the force exerted on the friction sleeve (located behind the cone) is measured by electrical methods and calculated at a minimum of every 20 cm of penetration. The force (total side friction) is measured when the midpoint of the friction sleeve is at a location which approximately coincides with the location of the cone at the previous cone reading. Stress is calculated by dividing the measured force by the surface area of the friction sleeve to determine friction sleeve resistance, f_s.

4.3 Some penetrometers are capable of registering pore water pressure induced during advancement of the penetrometer tip using an electric pore pressure transducer. These penetrometers are called "piezocones." The piezocone is advanced at a rate of 2 cm/s, and readings are taken at a minimum of every 20 cm of penetration. The dissipation of excess pore water pressure can be

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monitored by stopping penetration and observing the time required for pore pressure equalization.

5. Significance and Use

5.1 This test provides a detailed record of cone resistance which is useful for evaluation of site stratigraphy, homogeneity and depth to firm layers, voids or cavities, and other discontinuities. The addition of friction sleeves and pore pressure elements can provide an estimate of soil classification, and additional correlations with engineering properties of soils. When properly performed at suitable sites, the test provides a rapid means for determining subsurface conditions.

5.2 Electric cone penetrometers are capable of performing measurements at much closer intervals than 20 cm of penetration. Smaller measurement intervals provide a more detailed stratographic profile.

6. Terminology

6.1 Definitions are in accordance with USBR 3900.

6.2 Terms not included in USBR 3900 specific to this designation are:

6.2.1 *Apparent Load Transfer.*–Apparent resistance measured on either the cone or friction sleeve of an electric cone penetrometer while that element is in a no-load condition but the other element is loaded. Apparent load transfer is the sum of crosstalk, subtraction error, and mechanical load transfer.

6.2.2 *Baseline.*–A set of zero load readings, expressed in terms of apparent resistance, that are used as reference values during performance of testing and calibration.

6.2.3 *Cone.*–The conical point of a cone penetrometer on which the end bearing component of penetration resistance is developed. The cone has a 60-degree apex angle, a projected (horizontal plane) surface area or cone base area of 10 or 15 cm^2, and a cylindrical extension behind the cone base.

6.2.4 *Cone Penetrometer.*–A penetrometer in which the leading end of the penetrometer tip is a conical point designed for penetrating soil and for measuring the end-bearing component of penetration resistance.

6.2.5 *Cone Resistance, q_c.*–The end-bearing component of penetration resistance. The resistance to penetration developed on the cone is equal to the vertical force applied to the cone divided by the cone base area.

6.2.6 *Cone Sounding.*–An entire series of penetration tests performed at one location when using a cone penetrometer.

6.2.7 *Crosstalk.*–An apparent load transfer between the cone and the friction sleeve caused by interference between the seperate electronic channels.

6.2.8 *ECPT.*–Abbreviation for electric cone penetration test.

6.2.9 *Electric Cone Penetrometer.*–A cone or friction cone penetrometer that uses electric-force transducers, such as strain gauge load cells, built into a nontelescoping penetrometer tip for measuring, within the penetrometer tip, the component(s) of penetration resistance.

6.2.10 *End Bearing Resistance.*–Same as cone resistance.

6.2.11 *Friction Cone Penetrometer.*–A cone penetrometer with the additional capability of measuring the friction component of penetration resistance.

6.2.12 *Friction Ratio, R_f.*–The ratio of friction sleeve resistance, f_s, to cone resistance, q_c, measured at approximately the same depth, expressed as a percentage.

6.2.13 *Friction Reducer.*–A narrow local protuberance on the outside of the push rod surface, placed at a certain distance above the penetrometer tip, which is provided to reduce the total side friction on the push rods.

6.2.14 *Friction Sleeve Resistance, f_s.*–The friction component of penetration resistance developed on a friction sleeve, equal to the vertical shear force applied to the friction sleeve divided by its surface area.

6.2.15 *Friction Sleeve.*–An isolated cylindrical sleeve section on a penetrometer tip upon which the friction component of penetration resistance develops. The friction sleeve has a surface area of either 150 cm^2 or 225 cm^2, depending on the diameter of the penetrometer tip.

6.2.16 *FSO.*–Abbreviation for full-scale output. The output of an electronic force transducer when loaded to 100-percent rated capacity.

6.2.17 *Local Side Friction.*–Same as friction sleeve resistance.

6.2.18 *Penetration Resistance Measuring System.*–A measuring system that provides the means for transmitting information from the penetrometer tip and displaying the data at the surface where it can be seen or recorded. Typical electrical systems use strain gauges and a cable to sense and transmit forces while appropriate signal conditioning and analog or digital data are displayed at the surface.

6.2.19 *Penetrometer.*–An apparatus consisting of a series of cylindrical push rods with a terminal body (end section), called the penetrometer tip, and measuring devices for determination of the components of penetration resistance.

6.2.20 *Penetrometer Tip.*–The terminal body (end section) of the penetrometer which contains the active elements that sense the components of penetration resistance. The penetrometer tip may include additional electronic instrumentation for signal conditioning and amplification.

6.2.21 *Electric Piezocone Penetrometer.*–An electric penetrometer equipped with a low volume fluid chamber, porous element, and pressure transducer for determination of pore pressure at the porous element soil interface.

6.2.22 *Pore Pressure Ratio.*–The ratio of pore pressure in excess of hydrostatic pore pressure, Δ_u, (excess pore pressure) to cone resistance, q_c, expressed as a percentage. (Other definitions have been proposed and may be suitable for specific applications.)

6.2.23 *Push Rods.*–The thick-walled tubes or rods used to advance the penetrometer tip and to guide and shield the measuring system.

6.2.24 *Sleeve Friction and/or Resistance.*-Same as friction sleeve resistance.

6.2.25 *Subtraction Error.*-An apparent load transfer from the cone to the friction sleeve of a subtraction type electric cone penetrometer caused by minor voltage differences in response to load between the two strain element cells.

6.2.26 *Total Force,* Q_t.-The force needed to push the penetrometer tip/push-rod assembly into the soil.

6.2.27 *Total Cone Force,* Q_c.-Total force acting ~~on~~ the cone.

6.2.28 *Total Side Friction,* Q_{st}.-Total force minus total cone force.

7. Interferences

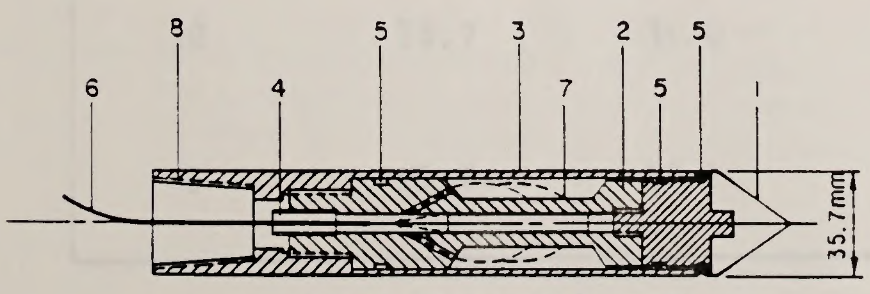
7.1 Refusal, deflection, or damage to the penetrometer may occur in coarse grained soil deposits with maximum particle sizes which approach or exceed the diameter of the cone.

7.2 Partially lithified and lithified deposits may cause refusal, deflection, or damage to the penetrometer.

7.3 Standard push rods can be damaged or broken under extreme loadings. The amount of force that push rods are able to sustain is a function of the unrestrained length of the rods and the weak links in the push rod-penetrometer tip string such as push rod joints and push rod-penetrometer tip connections. Generally, if total thrust exceeds 196 kN, standard push rods can be damaged.

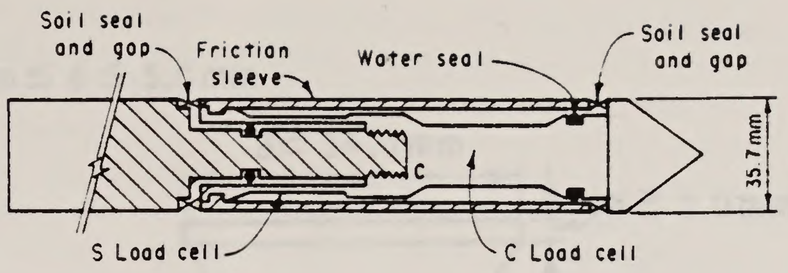
8. Apparatus

8.1 *Electric Cone Penetrometer Tip.*-The penetrometer tip should meet requirements as given below and in subparagraph 11.1. In a typical electric cone penetrometer tip (as shown on fig. 1), the force produced by cone resistance during penetration is measured by a single load cell in the penetrometer tip. In a typical electric friction cone penetrometer tip (as shown on fig. 2), the forces produced by friction sleeve resistance and cone resistance during penetration are measured by two load cells within the electric friction cone penetrometer tip. When friction sleeve elements are included, either independent or subtraction-type electric friction cone penetrometer tips are acceptable for use. In the subtraction-type electric friction cone penetrometer, the cone and sleeve both produce compressive forces on the load cells. The load cells are joined together in such a manner that the cell nearest the cone (the "C" cell on fig. 2b) measures the compressive force on the cone while the second cell (the "C+S" cell on fig. 2b) measures the sum of the compressive forces on both the cone and friction sleeve. The compressive force from just the friction sleeve is computed then by subtraction. Since friction sleeve forces are usually on the order of 1/10 to 1/100 of cone forces, the subtraction process is subject to a higher level of error than an independent measurement process. In the independent tension-type electric cone penetrometer tip, the cone produces a compression force on the cone load cell (the "C" cell on fig. 2a) while the friction sleeve produces a tensile force on the independent friction sleeve load cell (the "S" cell on fig. 2a). Since the friction sleeve cell strain gauges are designed to respond to a lower level of loading, subtraction errors are alleviated. This penetometer tip design results in a higher degree of accuracy in friction sleeve measurement. Equal end area friction sleeves are preferred for use. If these are not available, the end areas must be documented and the friction sleeve resistance compensated for differences in end areas. The friction sleeve load cell system must operate in such a way that the system is sensitive to only shear stresses applied to the friction sleeve and not to normal stresses.

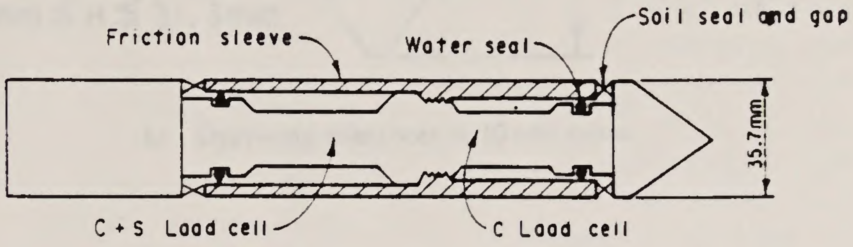


1. Conical point (10cm²) (cone)
2. Load cell
3. Protective mantle
4. Waterproof bushing
5. O-Rings - soil seal - gap
6. Cable
7. Strain gauges
8. Connection with rods

Figure 1. - Typical electric cone penetrometer tip (Robertson and Campanella, 1984 [2]).



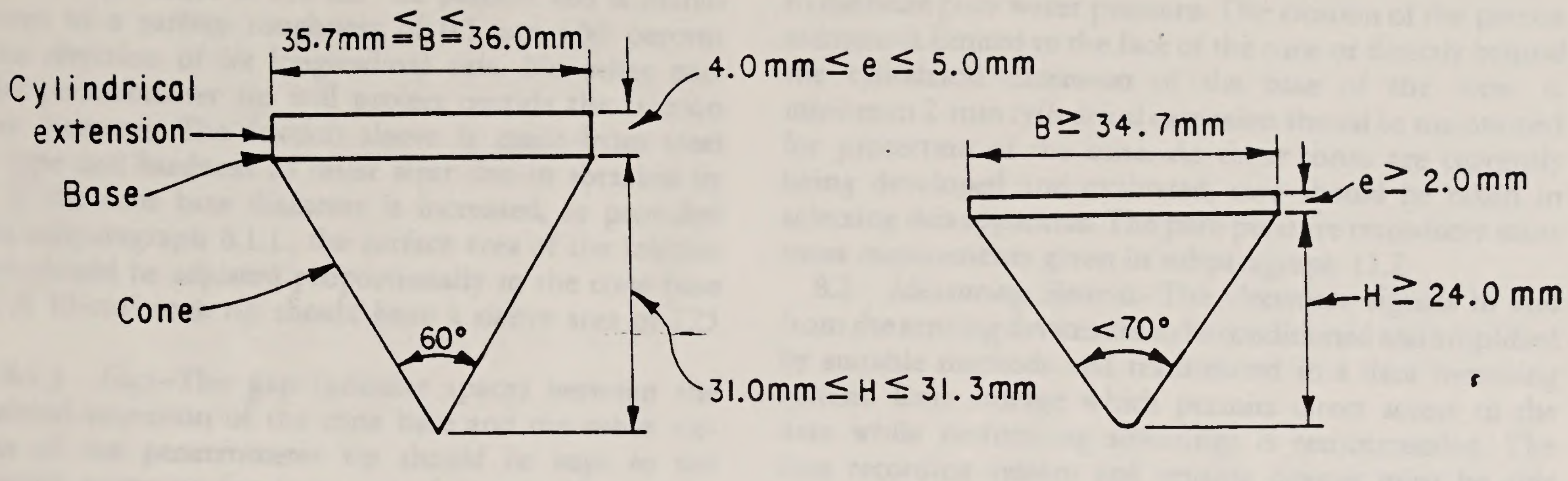
(a) Independent tension-type electric friction — cone penetrometer.



(b) Subtraction-type electric friction — cone penetrometer.

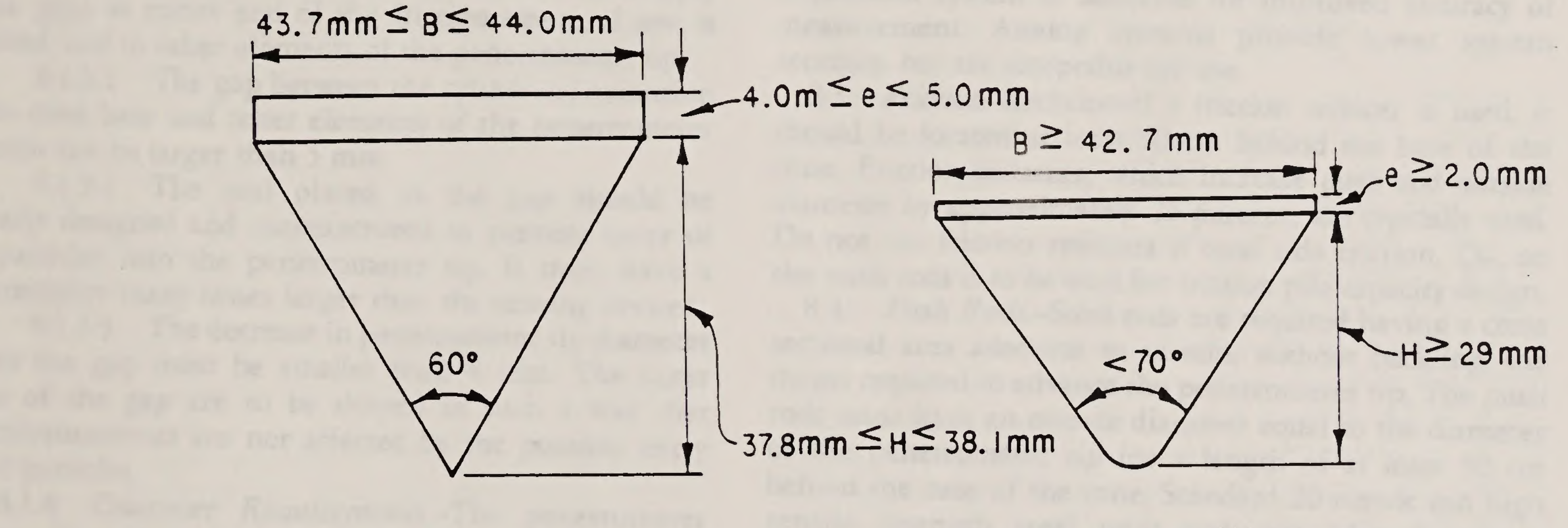
Figure 2. - Typical electric friction — cone penetrometer tip configurations (Schaap and Zuidberg, 1982 [1]).

8.1.1 *Cone.*-Nominal dimensions, with manufacturing and operating tolerances, for the cone are shown on figure 3. The cone has a base area of 10 cm² with an apex angle of 60 degrees. A cylinderical extension of 5 mm



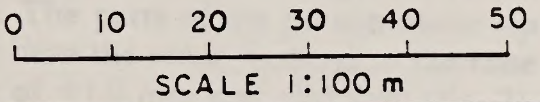
(a) Manufacturing tolerances of 10 cm² cones.

(b) Operating tolerances of 10 cm² cones.



(c) Manufacturing tolerances of 15 cm² cones.

(d) Operating tolerances of 15 cm² cones.



CONE BASE AREA cm^2	NOMINAL BASE DIAMETER B mm	NOMINAL CONE HEIGHT H mm	NOMINAL EXTENSION e mm	TOLERANCE MANUFACTURED (OPERATIONS) B mm	TOLERANCE MANUFACTURED (OPERATIONS) H mm	TOLERANCE MANUFACTURED (OPERATIONS) e mm
10	35.7	31.0	5.0	+ 0.3 - 0.0 (≥34.7)	+ 0.3 - 0.0 (≥24.0)	+0.0 - 1.0 (≥ 2.0)
15	43.7	37.8	5.0	+ 0.3 - 0.0 (≥42.7)	+ 0.3 - 0.0 (≥29.0)	+0.0 - 1.0 (≥2.0)

Figure 3. - Manufacturing and operating tolerances of cones.

or less should be located behind the base of the cone to protect the outer edges of the cone base from excessive wear. In certain cases, it may be desirable to increase the cone diameter. Increasing the diameter, while maintaining a constant force transducer accuracy, requires more force and therefore higher resolution capability in soft soils. The standard increase is to a base diameter which provides a cone base area of 15 cm² while maintaining a 60-degree apex angle. Nominal dimensions, with manufacturing and operating tolerences, for 15-cm² cones are shown on figure 3. The cone is made of steel of a type and hardness suitable to resist wear due to abrasion by soil.

8.1.2 *Friction Sleeve.*-The outside diameter of the manufactured friction sleeve and the operating diameter are equal to the diameter of the base of the cone with a tolerance of +0.35mm and -0.00 mm. The surface area

of the friction sleeve is 150 cm^2 ±2 percent and is manufactured to a surface roughness of 0.5 μm ±50 percent in the direction of its longitudinal axis. No other part of the penetrometer tip will project outside the friction sleeve diameter. The friction sleeve is made from steel of a type and hardness to resist wear due to abrasion by soil. If the cone base diameter is increased, as provided for in subparagraph 8.1.1., the surface area of the friction sleeve should be adjusted proportionally to the cone base area. A 15-cm^2 cone tip should have a sleeve area of 225 cm^2.

8.1.3 *Gap.*-The gap (annular space) between the cylindrical extension of the cone base and the other elements of the penetrometer tip should be kept to the minimum necessary for operation of the sensing devices and should be designed and constructed in such a way to prevent the entry of soil particles. Gap requirements apply to the gaps at either end of the friction sleeve, if one is included, and to other elements of the penetrometer tip.

8.1.3.1 The gap between the cylindrical extension of the cone base and other elements of the penetrometer tip must not be larger than 5 mm.

8.1.3.2 The seal placed in the gap should be properly designed and manufactured to prevent entry of soil particles into the penetrometer tip. It must have a deformability many times larger than the sensing devices.

8.1.3.3 The decrease in penetrometer tip diameter within the gap must be smaller than 4 mm. The outer limits of the gap are to be shaped in such a way that the measurements are not affected by the possible entry of soil particles.

8.1.4 *Diameter Requirements.*-The penetrometer tip must have the same diameter as the base of the cone, within the following tolerances, over a length of 50 cm behind the cone base. The parts of the penetrometer tip behind the cone must have the same diameter as the cone base with a tolerance of +1.0 mm and -0.3 mm (fig. 2). When a friction sleeve is included, the friction sleeve should be located within 10 cm behind the base of the cone. The friction sleeve diameter tolerance is given in subparagraph 8.1.2. The annular spaces and seals between the friction sleeve and other portions of the penetrometer tip must conform to the same specifications as described in subparagraph 8.1.3. The portion of the penetrometer tip located behind the friction sleeve, over a length equivalent to 12 cone base diameters, must have the same diameter as the friction sleeve with a tolerance of +0.0 mm and -0.3 mm.

8.1.5 The axis of the cone, the friction sleeve (if included), and the body of the penetrometer tip must be coincident.

8.1.6 *Sensing Devices.*-The typical load sensing device is a strain gauge load cell which contains temperature compensated bonded strain gauges. The configuration and location of strain gauges should be such that measurements are not influenced by possible eccentricity of loading.

8.1.7 *Electric Piezocone Penetrometer.*-Various electric cone penetrometer tips can contain low volume fluid chambers, porous elements, and pressure transducers to measure pore water pressure. The location of the porous element is limited to the face of the cone or directly behind the cylindrical extension of the base of the cone. A minimum 2-mm cylindrical extension should be maintained for protection of the cone. As these cones are currently being developed and evaluated, care should be taken in selecting this apparatus. The pore pressure transducer must meet requirements given in subparagraph 11.2.

8.2 *Measuring System.*-The electronic signals to and from the sensing devices are to be conditioned and amplified by suitable methods and transmitted to a data recording system. Data storage which permits direct access to the data while performing soundings is recommended. The data recording system and sensing devices must be able to satisfy calibration requirements of subparagraph 11.1 and those shown in the annex. A digitally based data acquisition system is desirable for improved accuracy of measurement. Analog systems provide lower system accuracy, but are acceptable for use.

8.3 *Friction Reducer.*-If a friction reducer is used, it should be located at least 50 cm behind the base of the cone. Friction reducers, which increase push rod outside diameter by approximately 25 percent, are typically used. Do not use friction reducers if total side friction, Q_{st}, on the push rods is to be used for friction pile capacity design.

8.4. *Push Rods.*-Steel rods are required having a cross sectional area adequate to sustain, without buckling, the thrust required to advance the penetrometer tip. The push rods must have an outside diameter equal to the diameter of the penetrometer tip for a length of at least 50 cm behind the base of the cone. Standard 20-metric ton high tensile strength steel push rods are 36-mm outside diameter, 16-mm inside diameter, and have a mass per unit length of 6.65 kg/m. Push rods are supplied in 1-meter lengths. The push rods must be secured together to bear against each other at the joints and form a rigid-jointed string of push rods. The deviation of push rod alignment from a straight axis should be held to a minimum, especially in the push rods near the pentrometer tip, to avoid excessive directional penetrometer drift. Generally, when a 1-meter long push rod is subjected to circular bending—resulting in 1 to 2 mm of center axis rod shortening—the push rod should be discarded. This corresponds to a horizontal deflection of 2 to 3 cm at the center of bending. When using push rods with prestrung electrical cable, the locations of push rods in the string should be varied periodically to avoid permanent curvature.

8.5 *Thrust Machine and Reaction.*-The thrust machine will provide a continuous stroke, preferably over a distance greater than 1 meter. The machine must advance the penetrometer tip and push rods at a smooth, constant rate (see subpar. 13.1.2) while the magnitude of thrust can fluctuate. The thrust machine must be anchored and/or ballasted so that it provides the necessary reaction for the penetrometer and does not move relative to the soil surface during thrust. These requirements preclude use of drilling rigs with a chain pulldown system and rigs whose reaction is transmitted through tires or other suspension systems which allow movement during sounding.

NOTE 2.-Cone penetration soundings usually require thrust capabilities ranging from 98 to 147 kN (10 to 15 metric tons). High mass ballasted vehicles can cause soil surface deformations which may affect penetrometer resistance(s) measured in near-surface layers. Anchored and/or ballasted vehicles may induce changes in ground surface reference level. If these conditions are evident, they should be noted in reports.

9. Reagents and Materials

9.1 *O-Ring Compound.*-A silicon compound ~~for~~ facilitating seals with O-rings.

9.2 *Glycerin* ($HOCH_2CH(OH)CH_2OH$).-For use in pore pressure measurement system.

10. Precautions

10.1 *Safety Precautions.*-Performance of the test usually involves use of a drill rig; therefore, safety requirements as outlined in the document cited under subparagraph 3.4, or in other applicable safety standards, should be observed.

10.2 *Technical Precautions — General*:

10.2.1 Use of penetrometer tip components that do not meet required tolerances or show visible signs of nonsymmetric wear can result in erroneous penetration resistance data.

10.2.2 The application of thrust in excess of rated capacity of the equipment can result in damage to equipment (see par. 7).

10.2.3 A cone sounding must not be performed any closer than 25 borehole diameters from any existing unbackfilled or uncased bore hole.

10.2.4 When performing cone penetration testing in prebored holes, an estimate of the depth below the prebored depth—which is disturbed by drilling—should be made and penetration resistance data obtained in this zone should be noted. Usually, this depth of disturbance is assumed to be equal to at least three borehole diameters.

10.2.5 Significant bending of the push rods can influence penetration resistance data. The use of a tabular rod guide is recommended at the base of the thrust machine and also in prebored holes to help prevent push rod bending.

10.2.6 Push rods not meeting requirements of subparagraph 8.4 may result in excessive directional penetrometer drift and possibly unreliable penetration resistance values.

10.2.7 Passing through or alongside obstructions may deflect the penetrometer and induce directional drift. Note any indications of encountering such obstructions, and be alert for possible subsequent improper penetrometer tip operation.

10.2.8 If the proper rate of advance of the penetrometer is not maintained for the entire stroke through the measurement interval, penetration resistance data may be erroneous.

10.2.9 Differences in penetrometer tip shape and method of advance (for example, between fixed-cone electric and free-cone mechanical operation) may result in significant differences in one or both of the components of penetration resistance.

10.3 *Technical Precautions—Electric Cone Penetrometer*:

10.3.1 Failure of O-ring seals can result in damage to or inaccurate readings from electronic force transducers (load cell). The O-ring seals should be inspected regularly for overall condition and watertightness.

10.3.2 Soil ingress between different elements of a penetrometer tip can result in unreliable data. Seals should be inspected after each sounding, maintained regularly, and replaced when necessary.

10.3.3 Electric cone penetrometer tips should be temperature compensated. If the shift in baseline reading after extracting the penetrometer tip from the soil is so large that the conditions of accuracy as defined in subparagraph 11.1.2.1 are no longer met, penetration resistance data should be noted as unreliable.

10.3.4 If baseline readings do not conform to allowable limits established by accuracy requirements in subparagraph 11.1.2.1, the penetrometer tip must be repaired and recalibrated or replaced.

10.3.5 Electric friction cone penetrometer tips having a friction sleeve end area ratio or a net area ratio not equal to 1.0 will yield cone and friction sleeve resistance data that are erroneous because of unequal dynamic pore pressures encountered during penetrometer tip advancement. The friction sleeve end area ratio is the ratio of the projected areas of top and bottom edges of the friction sleeve on which water pressure can act in the vertical direction. The net area ratio is the ratio of nominal base area of the cone to the area behind the base of the cone on which water pressure can act in a vertical direction. If penetrometer tips of this type are used, these effects should be noted in the report.

10.3.6 The electric piezocone penetrometer tip measures pore water pressures on the exterior of the penetrometer tip by transferring the pressure through a de-aired fluid system to a pressure transducer in the interior of the tip. The measurement system (consisting of transducer port, ports, and porous elements) must be completely saturated prior to testing. Entrained air must be removed from the fluid-filled system or pore pressure fluctuation during penetrometer tip advancement will be incorrect due to response lag from compression of air bubbles.

11. Calibration and Standardization

11.1 *Electric Cone Penetrometers*:

11.1.1 The requirements for newly manufactured or repaired electric cone penetrometers are of importance. Newly manufactured or repaired electric cone penetrometer tips are to be supplied with calibration records as described in the annex. Calibration procedures and requirements given in the annex are for subtraction-type electric cone penetrometers. Calibration requirements for independent-type electric cone penetrometers should equal or exceed those requirements. The calibration records must be

certified as correct by a registered professional engineer or other responsible engineer with knowledge and experience in materials testing for quality assurance. Applied forces or masses must be traceable to calibration standard forces or masses retained by the National Institute of Standards and Technology (National Bureau of Standards). Procedures for calibration of newly manufactured and repaired penetrometer tips are beyond the scope of normal field operating procedures.

11.1.2 Field calibration of electric cone penetrometers is required. Field calibration requires use of a loading device, calibrated to traceable calibration standards, that can independently apply forces up to 80 percent of rated capacity on the cone and friction sleeve load cells.

11.1.2.1 *Baseline Readings.*–Baseline or zero-load readings for both cone and friction sleeve load cells must be taken before and after each sounding. The initial baseline reading should be taken after warming electrical circuits for 15 to 30 minutes and in a temperature environment as close as possible to that of the material to be sounded. The penetrometer tip can be inserted in the ground while electrically warming circuits to stabilize its temperature and then extracted for determination of initial baseline. The baseline reading is a reliable indicator of output stability, temperature-induced apparent load, soil ingress, internal friction, threshold sensitivity, and unknown loading during zero setting. The change in field baseline versus initial reference baseline for both cone and friction sleeve load cells should not exceed 2 percent of FSO of the cone or friction sleeve. If the baseline shift exceeds 2 percent FSO, perform maintenance and cleaning, and perform a load range calibration as described in subparagraph 11.1.2.2. Prior to the load range calibration, obtain a new reference baseline for use as future comparison of field baseline, assuming the penetrometer meets load range requirements given in subparagraph 11.1.2.2. If the cone load cell baseline shift exceeds 2 percent FSO, the cone is likely damaged and will not meet load range criteria in subparagraph 11.1.2.2. Sleeve load cell baseline shift for subtraction-type penetrometers usually can exceed 2 percent FSO and still meet load range criteria. As a result new reference baselines are obtained prior to load range calibration.

11.1.2.2 *Working and Partial Load Range Calibrations.*–At the intervals specified below, working or partial load range calibrations are required to ensure proper linearity of the instrument over the working range of the load cell. Calibrations should be performed with all O-rings and seals in place. Working load range calibrations are to consist of a minimum of 7 points at 0, 2, 5, 10, 25, 50, and 75 percent of full-scale loading for cone and friction sleeve load cells independently. Partial load range calibration checks can be reduced to a minimum of 3 points at 2, 25, and 50 percent of full-scale loading. During load range calibrations, the amount of apparent load transfer during cone or friction sleeve loading must also be monitored. If, in the sounding process, soil ingress or other factors appear to have changed subtraction or baseline error through load transfer, the penetrometer tip should be subjected to a partial load range calibration after removal from the ground but prior to cleaning. Penetrometer tips, with data acquisition systems using fixed reference base lines, that do not meet the requirements given below or in subparagraph 11.1.2.1 must be discarded, recalibrated, or sent to the factory for repair.

Calibration parameter	*Element*	*Requirement*
Zero load shift	Cone and sleeve	≤2% FSO
Calibration error	Cone	±1.5% FSO band
Calibration error	Sleeve	±2.5% FSO band
Apparent load transfer	Cone	±1.0% FSO
Apparent load transfer	Sleeve	±0.2% FSO

For data acquisition systems using the actual best-fit calibration line obtained prior to sounding, linearity of the cone and friction sleeve must be within 1 and 2 percent of FSO, respectively.

11.1.2.2.1 Prior to performing a sounding on a new feature or project, all penetrometer tips must be subjected to full load range calibration.

11.1.2.2.2 During standard production testing, penetrometer tips used for soundings must be subjected to working load range calibration at intervals of once every 40 soundings (approximately every week).

11.1.2.2.3 During heavy production testing, penetrometer tips used for soundings must be subjected to partial load range calibrations daily.

11.2 *Pore Pressure Transducer.*–After the pressure transducer is installed in the penetrometer tip, it is to be calibrated in a water filled pressure chamber large enough to house the active sensing elements of the penetrometer tip. The pressure transducer baseline and apparent pressure at atmospheric pressure are obtained at room temperature. Baseline values are further checked at 0 to 30 °C. Thermal stability of the baseline value must be ≤1 percent FSO. The pressure transducer then is internally zeroed at atmospheric pressure and subjected to a load range calibration consisting of a minimum of five points of both loading and unloading to 80 percent of rated transducer capacity or 0.7 MPa (100 lbf/in^2), whichever is least. The calibration error must be ≤0.2 percent of the applied pressure. During hydrostatic loading, cone and friction sleeve load cell output also should be monitored and recorded to evaluate effects of pressure change on these elements.

12. Conditioning

12.1 Electric cone penetrometer and data acquisition systems should be powered for 15 to 30 minutes to stabilize electric circuits before performing soundings.

12.2 Electric piezocone penetrometer soundings require special preparation of the transmitting fluid and porous elements such that entrained air is removed from the system (see subpar. 13.3).

13. Procedure

13.1 *General Requirements*:

13.1.1 Position the thrust machine over the location of the sounding, and lower leveling jacks to raise the

machine mass off the suspension system. Set the hydraulic rams of the penetrometer thrust system to as near vertical as possible. The maximum acceptable deviation of thrust direction is 2 degrees from vertical. The axis of the push rods must coincide with the thrust direction.

13.1.2 Set the hydraulic ram feed rate to advance the penetrometer at a rate of 2.0±0.5 cm/s for all electric cone penetrometers. This rate must be maintained during the entire stroke — even if readings are only taken at intervals.

13.1.3 Check push rods for straightness as required in subparagraph 8.4. Push rods are assembled and tightened by hand, but care must be taken to ensure that the shoulders are tightly butted to prevent damage to the push rods. With electric cone penetrometers, the cable is prestrung through the push rods. Add a friction reducer to the string of push rods — usually the first push rod behind the penetrometer tip.

13.1.4 Inspect penetrometer tips before and after soundings for damage, soil ingress, and wear. In very soft and sensitive soils, dismantle electrical cone penetrometer tips after each sounding to clean and lubricate as required. If damage is found after a sounding, this information must be noted and recorded on the sounding data record.

13.2 *Electric Cone and Friction Cone Penetrometers*:

13.2.1 Power the penetrometer tip and data acquisition system for 15 to 30 minutes.

13.2.2 Perform an initial short penetration test hole; stop penetration and allow the penetrometer tip to reach soil temperature. Withdraw the penetrometer tip, and record baseline readings with the penetrometer tip hanging freely in air or in water, out of direct sunlight. Compare baseline readings with the reference baseline readings for the requirements given in subparagraph 11.1.2.1.

13.2.3 Measure the depth at which readings were taken with an accuracy of ±10 cm from the ground surface.

13.2.4 Determine the cone resistance, or cone resistance and friction sleeve resistance, continuously with depth and record the data at intervals of depth not exceeding 20 cm. With electric cone and friction cone penetrometers, it is desirable to obtain data at increments of 5 cm or less.

13.2.5 At the end of a sounding, extract the penetrometer tip, obtain a final set of baseline readings with the penetrometer tip hanging freely in air or in water, and check them against the initial and reference baselines. Record initial and final baselines on all documents related to the sounding.

13.3 *Electric Piezocone Penetrometers*:

13.3.1 Prepare porous elements using one of the following techniques:

- A pure glycerin bath under a vacuum of at least one atmosphere
- An ultrasonic bath with low heat for 3 hours
- Using de-aired water with the porous elements immersed in boiling water for 4 to 5 hours
- Other suitable means

Porous elements may be prepared and stored in containers of the de-aired fluid medium as long as the containers are evacuated and sealed from air entry.

13.3.2 Assemble the piezoelements with all fluid chambers submerged in the de-aired medium used to prepare the elements. Flush all confined areas with fluid to remove air bubbles. Tighten the cone to effectively seal the flat surfaces. Protect the assembled system from cavitation by enclosing the porous element inside a fluid-filled plastic bag or cap sealed to the penetrometer tip. When sealing, do not pressurize the sealed cap as this will affect initial baseline readings. In order to check that air has been effectively removed from the system and to evaluate response time, subject the assembled penetrometer tip enclosed in a fluid-filled pressure chamber to pressure testing. Response time should be practically instantaneous to pressure application.

13.3.3 When using de-aired water as the fluid medium, it will be necessary to prebore or sound with a pilot penetrometer tip to the water table. The protective cap must be removed during penetration into the soil. When using glycerin, which is more resistant to cavitation than water, it may be possible to penetrate unsaturated layers without cavitating the system and alleviate preboring and element protection requirements.

13.3.4 Record baseline readings with the penetrometer tip hanging freely in air, out of direct sunlight. Compare baseline readings with reference baseline readings for requirements given in subparagraphs 11.1.2.1 and 11.2.

13.3.5 Follow procedures in subparagraphs 13.3.4 and 13.2.5 with the addition of recording pore pressure.

13.4 *Penetrometer Operation and Data Interpretation — Guidelines*:

13.4.1 *Directional Drift of Penetrometer*:

13.4.1.1 For penetration depths exceeding about 12 meters, the penetrometer will drift directionally from vertical alignment. Large deviations in inclination can create nonuniform loading and result in unreliable penetration resistance data. Reduce drift by accurately setting thrust alignment and using push rods which meet tolerances given in subparagraph 8.4.

13.4.1.2 Passing through or along side obstructions such as boulders, cobbles, coarse gravel, soil concretions, thin rock layers, or inclined dense layers will deflect the penetrometer tip and induce drifting. Note and record any indication of encountering such obstructions, and be alert for possible subsequent improper penetrometer tip operations as a sign of serious directional drift.

13.4.1.3 Penetrometer inclination is typically monitored in electric cone penetrometers. Limitations on inclination should be imposed in the system to prevent damage to push rods and nonsymmetric loading of the penetrometer tip. Generally, a 2-degree change in inclination over 1 meter of penetration can impose detrimental push rod bending, and soundings should be terminated. Total drift of over 12 degrees in 10 meters of penetration imposes nonsymmetric loading and, if this should occur, the sounding should be terminated.

13.4.2 *Push Rod Addition Interruptions.*–Short duration interruptions in the penetration rate during addition of each new push rod, can affect initial cone and friction sleeve readings at the beginning of the next push. Note and record the depths at which push rods are added.

13.4.3 *Piezocone Pore Pressure Dissipation Interruptions.*-Pore pressure dissipation studies, for which soundings are stopped for varying time durations, can affect the initial cone, friction sleeve, and dynamic pore pressure readings at resumption of cone penetration. If dissipation tests are performed, be aware of possible rebound effects on initial excess pore pressures. Note and record the depth and duration for which dissipation values are taken.

13.4.4 *Interruptions Due to Obstructions.*-If obstructions are encountered and normal advance of the sounding is stopped to bore through the obstructions, obtain further penetration resistance data only after the penetrometer tip has passed through the estimated zone of disturbance due to drilling. As an alternative, readings may be continued without first making the additional penetration and the disturbed zone evaluated from these data. Note and record the depth and thickness of obstructions and disturbed zones in areas where obstructions are drilled through.

13.4.5 *Unusual Occurrences.*-As data are recorded, it is important to note unusual occurrences in testing. When penetrating gravels, it is important to note "crunching" sounds which may occur when particle size and percentage of coarse particles begin to influence penetration. In many cases, it is important to note the magnitude of thrust required to advance the penetrometer to evaluate when thrust capacity may be exceeded.

13.5 *Withdrawal*:

13.5.1 Withdraw the push rods and penetrometer tip as soon as possible after attaining complete sounding depth.

13.5.2 Upon complete withdrawal of the penetrometer, inspect the penetrometer tip for proper operation.

14. Calculations

14.1 *Cone Resistance,* q_c:

$$q_c = \frac{Q_c}{A_c} \qquad (1)$$

where:

q_c = cone resistance, ton/ft^2, kgf/cm^2, or MPa
Q_c = force on cone, ton, kgf, or kN
A_c = cone base area, typically 10 cm^2, ft^2 or cm^2

14.2 *Friction Sleeve Resistance,* f_s:

$$f_s = \frac{Q_s}{A_s} \qquad (2)$$

where:

f_s = friction sleeve resistance, ton/ft^2, kgf/cm^2, or kPa
Q_s = force on friction sleeve, ton, kgf, or kN
A_s = area of friction sleeve, typically 150 cm^2, ft^2, or cm^2

14.3 *Friction Ratio,* R_f:

$$R_f = 100\left(\frac{f_s}{q_c}\right) \qquad (3)$$

where:

R_f = friction ratio, %
f_s = friction sleeve resistance, ton/ft^2, kgf/cm^2, or kPa
q_c = cone resistance, ton/ft^2, kgf/cm^2, or kPa
100 = convert from decimal to percent

Determination of the friction ratio requires obtaining a cone resistance and friction sleeve resistance at the same point in the soil mass. Typically, a previous cone resistance reading at friction sleeve midpoint depth is used for the calculations.

NOTE 3.-In some cases, if readings are compared at the same point in a soil mass which has alternating layers of soft and hard materials, nonexistent layers will be falsely observed in the data because cone resistance is sensed, to varying degrees, ahead of the cone. To compensate, the sensing distance ahead of the cone can be varied such that the cone resistance is actually recorded above or below friction sleeve midheight.

NOTE 4.-The friction sleeve resistance and friction ratio obtained from the mechanical friction cone penetrometer will differ considerably from values obtained from electric friction cone penetrometers. When using soil classification charts which use R_f and q_c, it is important to use charts based on correlations for the type of penetrometer being used.

14.4 *Electric Cone Penetrometers.*-Most electric cone penetrometers in use at the present time measure a change in voltage across a strain gauge element to determine change in length of the strain element. Using known constitutive relationships between stress and strain for the strain element, the applied load may be determined for the cone or friction sleeve. The applied loads then may be converted to stress using the basic equations given in subparagraphs 14.1 and 14.2. Since there are a wide variety of additional, optional measurements currently being obtained with electric cone penetrometers and new ones being continually developed, it is beyond the scope of this procedure to detail the makeup, adjustments, and calculations for these optional measurements. Questions regarding current systems in use or acquisition of new data reduction systems can be directed to the Bureau's Denver Office, Research and Laboratory Services Division, D-3760, Denver, Colorado 80225.

15. Report

15.1 *General*:

Each sounding log should provide as a minimum:

Operator name	Sounding No.
Project information	Sounding location
Feature notes	Water surface elevation (if available)
Sounding date	

Reports should contain information concerning:

Equipment used	Tabular graph data
Procedures followed	Graphs
Calibration information	

The report should contain a text that discusses items required in subparagraphs 15.2 and 15.3.

Each sounding should be documented with:

A geologic log
Sounding plot
Accompanying tabular output

The comments should contain notes on equipment and procedures — particular to the individual sounding.

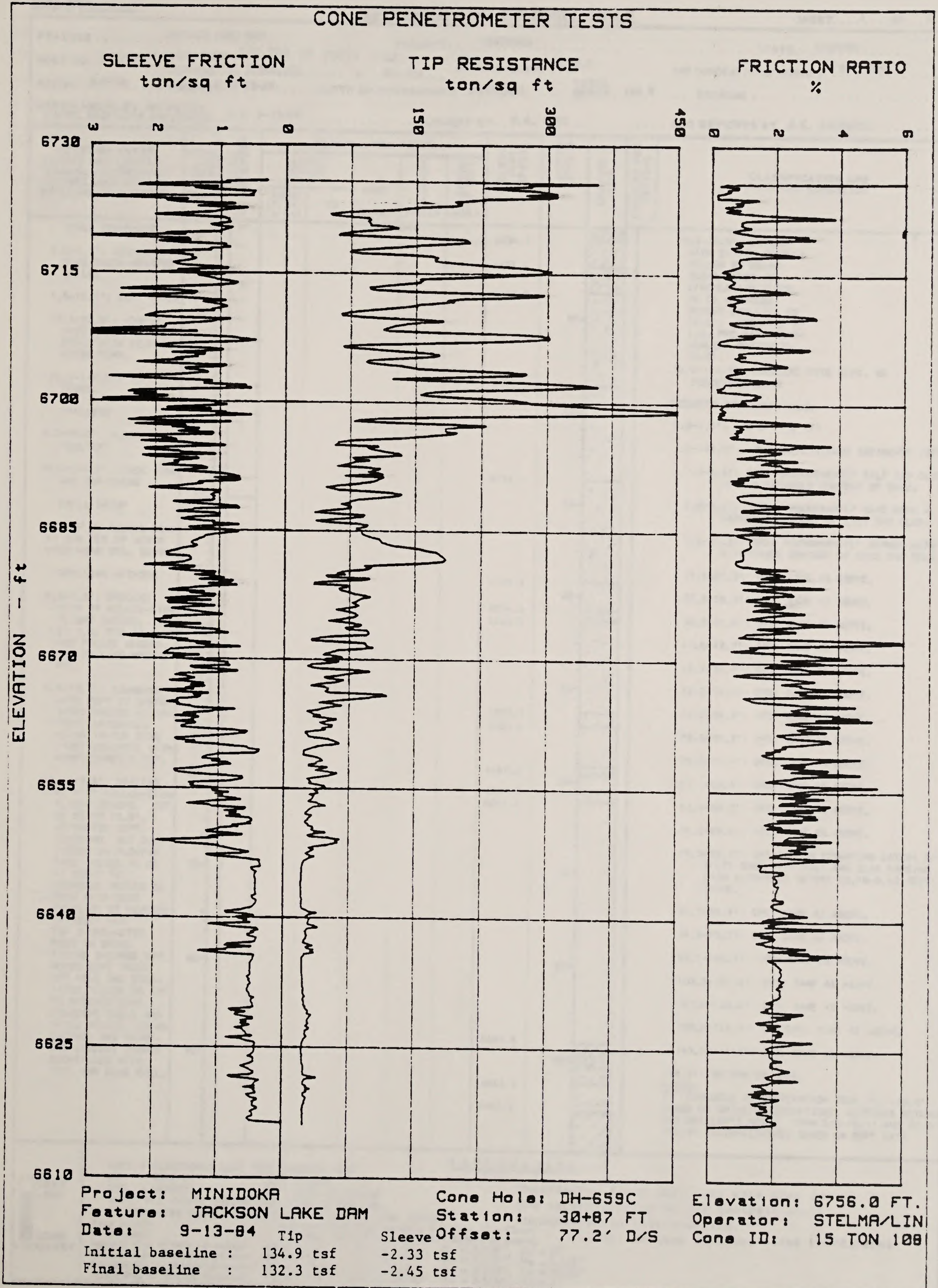
15.2 *Equipment.*-The report should include notes concerning:

- Penetrometer manufacturer
- Types of penetrometer tips used
- Penetrometer details such as friction sleeve end areas
- Serial numbers of penetrometer tips
- Pressure gauges
- Type of thrust machine
- Method used to provide reaction force — with notes as to possible surface deformations
- Type of friction reduction system (if any)
- Method of recording data
- Condition of pushrods and penetrometer tip after withdrawal
- Any special difficulties or other observations concerning performance of the equipment

15.3 *Calibration Certifications.*-Calibrations of Bureau-owned equipment should be retained in offices and maintained as outlined in paragraph 11. Soundings performed under contract by others require submittal of calibration records (in conformance with requirements given in para. 11) prior to performance of the contract, for review by the contracting officer. After performance of the contract, the additional field calibration documents (as outlined in par. 11) will be submitted with the report. Field calibration data consisting of pre- and post-sounding baseline values are to be reported with each individual sounding.

15.4 *Graphs.*-Every report of electric cone penetration sounding is to include a cone resistance plot, q_c (ton/ft^2, kgf/cm^2, or kPa) with depth below ground surface (ft or m). (See fig. 4 for an example plot.) Friction cone soundings will include the friction sleeve resistance, f_s (ton/ft^2, kgf/cm^2, or kPa), and friction ratio, R_f (%), on the same plot. The plots should indicate locations of push rod changes and other interruptions as outlined in subparagraphs 13.4.2 through 13.4.5. If it is impossible to show locations of interruptions on the report plots, provide a secondary plot such as an analog strip chart or notes of the occurrences of interruptions. As a minimum, the plot should provide information as outlined in subparagraph 15.1. Electric piezocone penetrometer soundings should provide an additional plot of pore pressure versus depth. If pore pressure ratios using a different definition than that given in subparagraph 6.1.22 are to be reported, the definition should be given on the plots. For uniform presentation of data, the vertical axis (ordinate) should display depth and the horizontal axis (abscissa) should display the test values. An example plot is shown on figure 4. An example of a completed geologic log is shown on figure 5.

15.5 *Report Requirements for Specifications.*-Each sounding to be displayed is to consist of two parts. First, a geologic log of the drill hole which contains report requirements given in subparagraphs 15.1 and 15.2 and any special interpretations or additional data obtained in conjunction with the sounding; second, plots meeting requirements given in subparagraph 15.4.



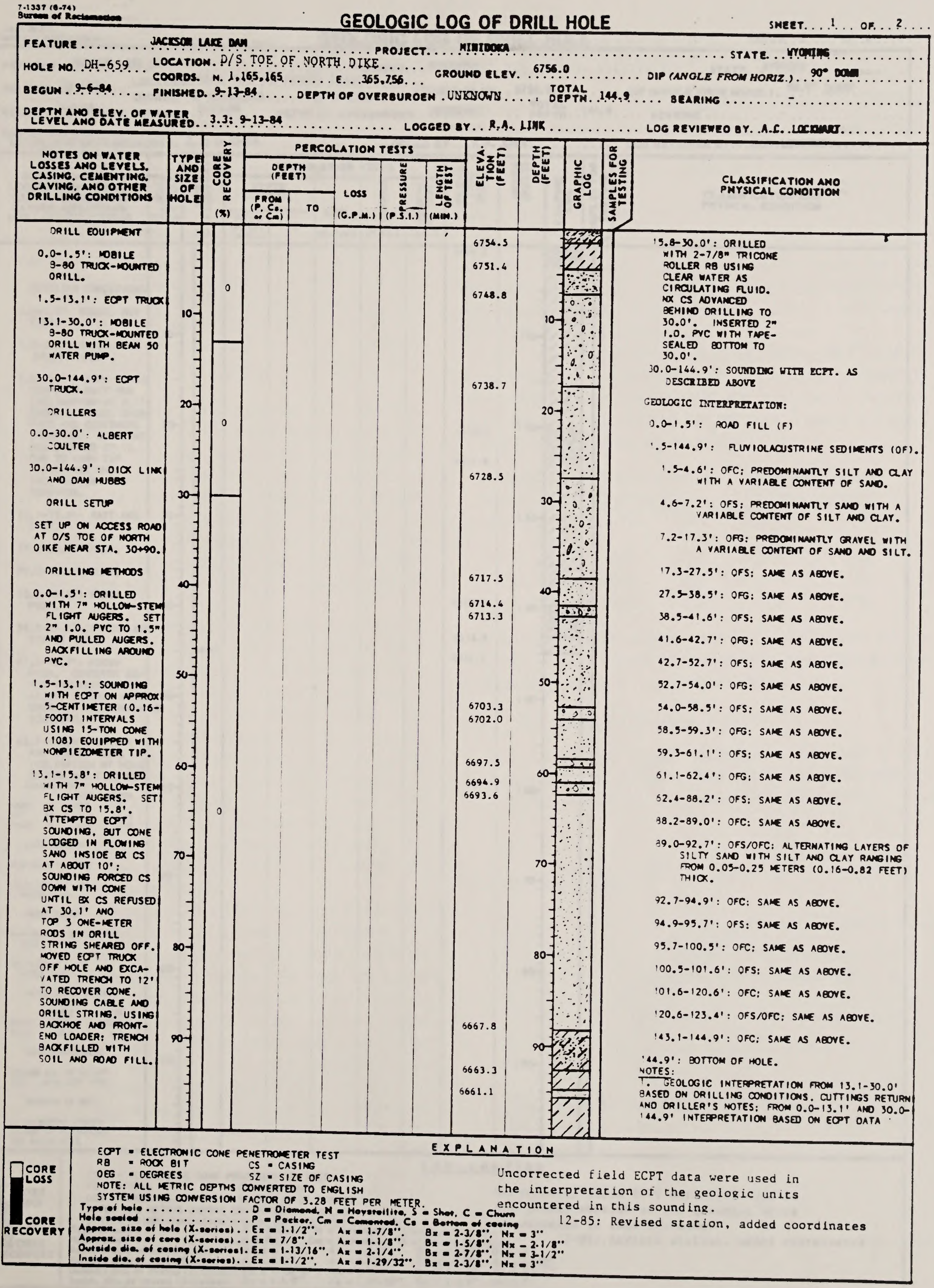
Project: MINIDOKA
Feature: JACKSON LAKE DAM
Date: 9-13-84

Cone Hole: DH-659C
Station: 30+87 FT
Offset: 77.2′ D/S

Elevation: 6756.0 FT.
Operator: STELMA/LIN
Cone ID: 15 TON 108

	Tip	Sleeve
Initial baseline :	134.9 tsf	-2.33 tsf
Final baseline :	132.3 tsf	-2.45 tsf

Figure 4. - Cone penetrometer tests — example.



7-1337 (6-74)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE JACKSON LAKE DAM
PROJECT MINIDOKA
STATE WYOMING
HOLE NO. DH-659
LOCATION D/S TOE OF NORTH DIKE
COORDS. N. 1,165,165 E. 365,756
GROUND ELEV. 6756.0
DIP (ANGLE FROM HORIZ.) 90° DOWN
BEGUN 9-6-84
FINISHED 9-13-84
DEPTH OF OVERBURDEN UNKNOWN
TOTAL DEPTH 144.9
BEARING -
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 3.3; 9-13-84
LOGGED BY R.A. LINK
LOG REVIEWED BY A.C. LOCKHART

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION

DRILL EQUIPMENT

0.0-1.5': MOBILE B-80 TRUCK-MOUNTED DRILL.

1.5-13.1': ECPT TRUCK.

13.1-30.0': MOBILE B-80 TRUCK-MOUNTED DRILL WITH BEAN 50 WATER PUMP.

30.0-144.9': ECPT TRUCK.

DRILLERS

0.0-30.0': ALBERT COULTER

30.0-144.9': DICK LINK AND DAN HUBBS

DRILL SETUP

SET UP ON ACCESS ROAD AT D/S TOE OF NORTH DIKE NEAR STA. 30+90.

DRILLING METHODS

0.0-1.5': DRILLED WITH 7" HOLLOW-STEM FLIGHT AUGERS. SET 2" I.D. PVC TO 1.5" AND PULLED AUGERS. BACKFILLING AROUND PVC.

1.5-13.1': SOUNDING WITH ECPT ON APPROX 5-CENTIMETER (0.16-FOOT) INTERVALS USING 15-TON CONE (108) EQUIPPED WITH NONPIEZOMETER TIP.

13.1-15.8': DRILLED WITH 7" HOLLOW-STEM FLIGHT AUGERS. SET BX CS TO 15.8'. ATTEMPTED ECPT SOUNDING, BUT CONE LODGED IN FLOWING SAND INSIDE BX CS AT ABOUT 10'; SOUNDING FORCED CS DOWN WITH CONE UNTIL BX CS REFUSED AT 30.1' AND TOP 3 ONE-METER RODS IN DRILL STRING SHEARED OFF. MOVED ECPT TRUCK OFF HOLE AND EXCAVATED TRENCH TO 12' TO RECOVER CONE, SOUNDING CABLE AND DRILL STRING, USING BACKHOE AND FRONT-END LOADER; TRENCH BACKFILLED WITH SOIL AND ROAD FILL.

15.8-30.0': DRILLED WITH 2-7/8" TRICONE ROLLER RB USING CLEAR WATER AS CIRCULATING FLUID. NX CS ADVANCED BEHIND DRILLING TO 30.0'. INSERTED 2" I.D. PVC WITH TAPE-SEALED BOTTOM TO 30.0'.

30.0-144.9': SOUNDING WITH ECPT. AS DESCRIBED ABOVE

GEOLOGIC INTERPRETATION:

0.0-1.5': ROAD FILL (F)

1.5-144.9': FLUVIOLACUSTRINE SEDIMENTS (OF).

1.5-4.6': OFC: PREDOMINANTLY SILT AND CLAY WITH A VARIABLE CONTENT OF SAND.

4.6-7.2': OFS: PREDOMINANTLY SAND WITH A VARIABLE CONTENT OF SILT AND CLAY.

7.2-17.3': OFG: PREDOMINANTLY GRAVEL WITH A VARIABLE CONTENT OF SAND AND SILT.

17.3-27.5': OFS: SAME AS ABOVE.

27.5-38.5': OFG: SAME AS ABOVE.

38.5-41.6': OFS: SAME AS ABOVE.

41.6-42.7': OFG: SAME AS ABOVE.

42.7-52.7': OFS: SAME AS ABOVE.

52.7-54.0': OFG: SAME AS ABOVE.

54.0-58.5': OFS: SAME AS ABOVE.

58.5-59.3': OFG: SAME AS ABOVE.

59.3-61.1': OFS: SAME AS ABOVE.

61.1-62.4': OFG: SAME AS ABOVE.

62.4-88.2': OFS: SAME AS ABOVE.

88.2-89.0': OFC: SAME AS ABOVE.

89.0-92.7': OFS/OFC: ALTERNATING LAYERS OF SILTY SAND WITH SILT AND CLAY RANGING FROM 0.05-0.25 METERS (0.16-0.82 FEET) THICK.

92.7-94.9': OFC: SAME AS ABOVE.

94.9-95.7': OFS: SAME AS ABOVE.

95.7-100.5': OFC: SAME AS ABOVE.

100.5-101.6': OFS: SAME AS ABOVE.

101.6-120.6': OFC: SAME AS ABOVE.

120.6-123.4': OFS/OFC: SAME AS ABOVE.

143.1-144.9': OFC: SAME AS ABOVE.

144.9': BOTTOM OF HOLE.

NOTES:

1. GEOLOGIC INTERPRETATION FROM 13.1-30.0' BASED ON DRILLING CONDITIONS, CUTTINGS RETURN AND DRILLER'S NOTES; FROM 0.0-13.1' AND 30.0-144.9' INTERPRETATION BASED ON ECPT DATA

EXPLANATION

☐ CORE LOSS
■ CORE RECOVERY

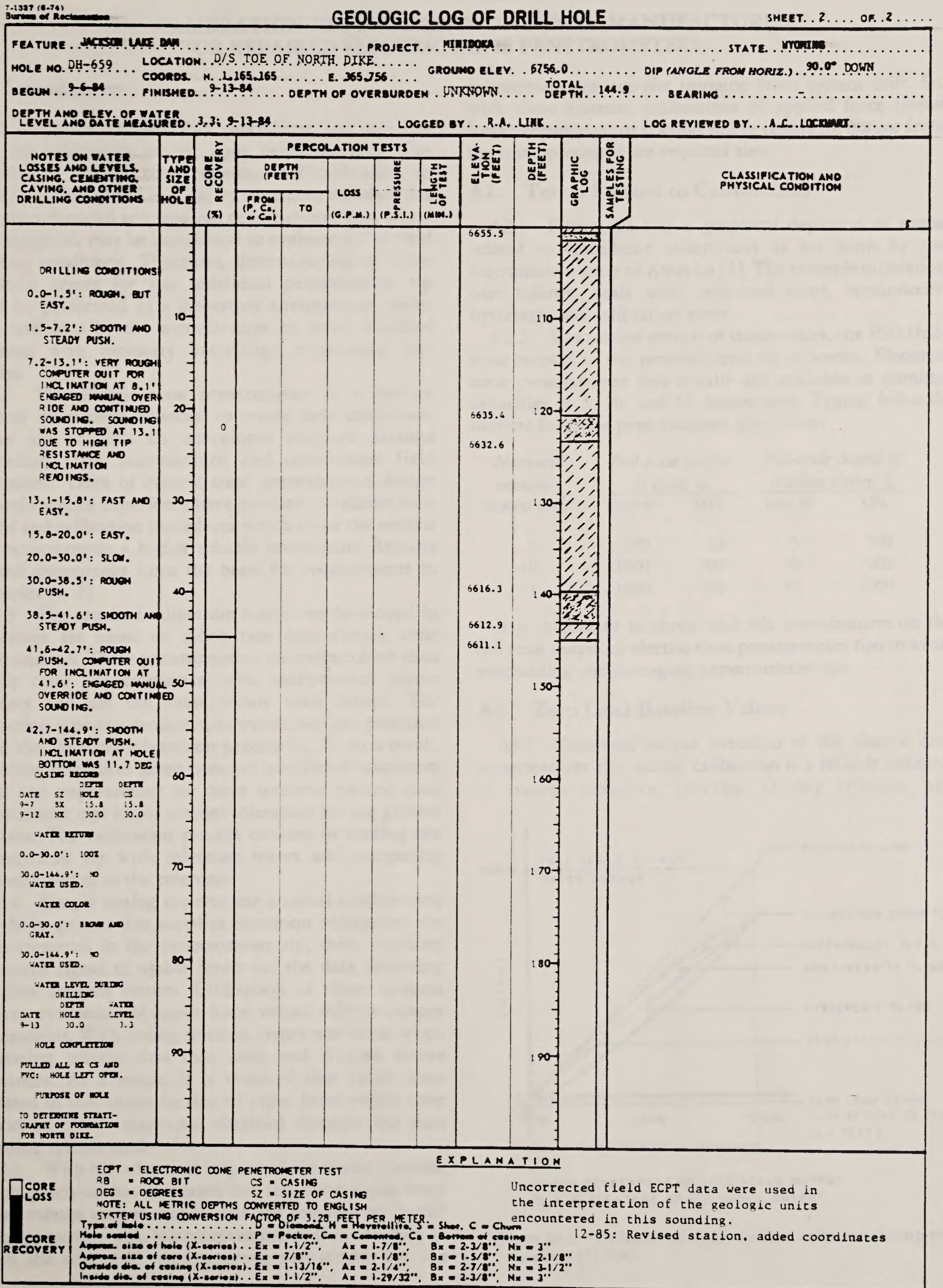
ECPT = ELECTRONIC CONE PENETROMETER TEST
RB = ROCK BIT
DEG = DEGREES
CS = CASING
SZ = SIZE OF CASING
NOTE: ALL METRIC DEPTHS CONVERTED TO ENGLISH SYSTEM USING CONVERSION FACTOR OF 3.28 FEET PER METER.

Type of hole . . . . D = Diamond, N = Hoystreilite, S = Shot, C = Churn
Hole sealed . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series). . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

Uncorrected field ECPT data were used in the interpretation of the geologic units encountered in this sounding.

12-85: Revised station, added coordinates

Figure 5. - Geologic log of drill hole (sheet 1 of 2) — example.



7-1337 (8-74)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE JACKSON LAKE DAM PROJECT MINIDOKA STATE WYOMING
HOLE NO. DH-659 LOCATION D/S TOE OF NORTH DIKE GROUND ELEV. 6756.0 DIP (ANGLE FROM HORIZ.) 90.0° DOWN
COORDS. N. 1,165,165 E. 365,756
BEGUN 9-6-84 FINISHED 9-13-84 DEPTH OF OVERBURDEN UNKNOWN TOTAL DEPTH 144.9 BEARING -
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 3.3; 9-13-84 LOGGED BY R.A. LINK LOG REVIEWED BY A.C. LOCKHART

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION

DRILLING CONDITIONS:

0.0-1.5': ROUGH, BUT EASY.

1.5-7.2': SMOOTH AND STEADY PUSH.

7.2-13.1': VERY ROUGH; COMPUTER QUIT FOR INCLINATION AT 8.1'; ENGAGED MANUAL OVERRIDE AND CONTINUED SOUNDING. SOUNDING WAS STOPPED AT 13.1' DUE TO HIGH TIP RESISTANCE AND INCLINATION READINGS.

13.1-15.8': FAST AND EASY.

15.8-20.0': EASY.

20.0-30.0': SLOW.

30.0-38.5': ROUGH PUSH.

38.5-41.6': SMOOTH AND STEADY PUSH.

41.6-42.7': ROUGH PUSH. COMPUTER QUIT FOR INCLINATION AT 41.6'; ENGAGED MANUAL OVERRIDE AND CONTINUED SOUNDING.

42.7-144.9': SMOOTH AND STEADY PUSH. INCLINATION AT HOLE BOTTOM WAS 11.7 DEG

CASING RECORD

DATE	SZ	DEPTH HOLE	DEPTH CS
9-7	BX	15.8	15.8
9-12	NX	30.0	30.0

WATER RETURN

0.0-30.0': 100%

30.0-144.9': NO WATER USED.

WATER COLOR

0.0-30.0': BROWN AND GRAY.

30.0-144.9': NO WATER USED.

WATER LEVEL DURING DRILLING

DATE	DEPTH HOLE	WATER LEVEL
9-13	30.0	3.3

HOLE COMPLETION

PULLED ALL NX CS AND PVC: HOLE LEFT OPEN.

PURPOSE OF HOLE

TO DETERMINE STRATIGRAPHY OF FOUNDATION FOR NORTH DIKE.

EXPLANATION

ECPT = ELECTRONIC CONE PENETROMETER TEST
RB = ROCK BIT
DEG = DEGREES
CS = CASING
SZ = SIZE OF CASING
NOTE: ALL METRIC DEPTHS CONVERTED TO ENGLISH SYSTEM USING CONVERSION FACTOR OF 3.28 FEET PER METER.

Type of hole .... D = Diamond, H = Hevstellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

Uncorrected field ECPT data were used in the interpretation of the geologic units encountered in this sounding.

12-85: Revised station, added coordinates

Figure 5. - Geologic log of drill hole (sheet 2 of 2) — example.

ANNEX

A1. CALIBRATION REQUIREMENTS ON NEWLY MANUFACTURED OR REPAIRED ELECTRIC CONE PENETROMETERS

A1. Introduction

A1.1 This annex describes procedures and requirements for calibrating electric cone penetrometers. The evaluation of electric cone penetrometer calibration as described in this annex is a quality assurance standard for newly manufactured and repaired penetrometer tips. Many of the standards may be impractical to evaluate under field operating conditions. Therefore, determination of these calibration errors for any individual penetrometer tip should be performed in a laboratory environment under ideal conditions by the manufacturer or other qualified personnel with necessary knowledge, experience, and facilities.

A1.2 The electric cone penetrometer is a delicate electrical instrument subjected to severe field conditions. Proper use of such an instrument requires detailed calibration after manufacture and continuous field calibrations. Years of electric cone penetrometer design and performance experience have resulted in refined cone designs and calibration procedures which make the electric cone penetrometer a highly reliable instrument. Reports of these experiences form the basis for requirements in this annex [1, 2].

A1.3 The required calibration tolerances developed in this annex are based on subtraction type electric cone penetrometers. These penetrometers are more robust than electric cone penetrometers with independent strain elements and are the most widely used design. The subtraction type penetrometer, however, has less precision due to the electrical subtraction process [1, 2]. As a result, calibration tolerances given here are considered maximum values and requirements for more sensitive electric cone penetrometer tips imply smaller tolerances having greater precision. The calibration process consists of loading the penetrometer tip with reference forces and comparing measured output to the reference.

A1.4 Simple analog systems use a signal conditioning unit above ground that supplies excitation voltages to the strain elements in the penetrometer tip, then amplifies the return signal to usable levels for the data recording and data analysis system. Calibration of these systems requires evaluation of input force versus voltage output relationships. With analog systems, errors may occur when integrating voltage data into cone and friction sleeve resistances. As a result, it is required that calibrations discussed in this annex be that of input force versus cone or friction sleeve resistance obtained through the data recording system used.

A1.5 With the advent of improved electronic systems, system precision has increased but the same input force versus voltage output calibrations are required to "tune" the penetrometer tip. Microprocessors reduce the data to obtain the cone and friction sleeve resistances, but the microprocessors are not immune from system drift. So, with these systems, calibrations of applied force (input force) versus cone or friction sleeve resistance output from the microprocessor are required also.

A2. Terms Related to Calibrations

A2.1 Figure A1.1 is a graphical depiction of terms related to transducer calibrations as set forth by the Instrument Society of America [1]. The example calibration that follows, deals with zero-load error, nonlinearity, hysteresis, and calibration error.

A2.2 To evaluate several of these values, the FSO (full-scale output) of the penetrometer tip is needed. Electrical cone penetrometer tips usually are available in nominal capacities of 5, 10, and 15 metric tons. Typical full-scale outputs for these penetrometer tips follow.

Nominal capacity, metric tons	*Full-scale output of cone, q_c*		*Full-scale output of friction sleeve, f_s*	
	ton/ft^2	MPa	ton/ft^2	kPa
5	500	50	5	500
10	1000	100	10	1000
15	1000	100	10	1000

It is important to check with the manufacturer on the full scale output of electric cone penetrometer tips to avoid overloading and damaging penetrometer tips.

A3. Zero Load Baseline Values

A3.1 Zero-load output variation of the electric cone penetrometer tips during calibration is a reliable indicator of output stability, internal O-ring friction, and

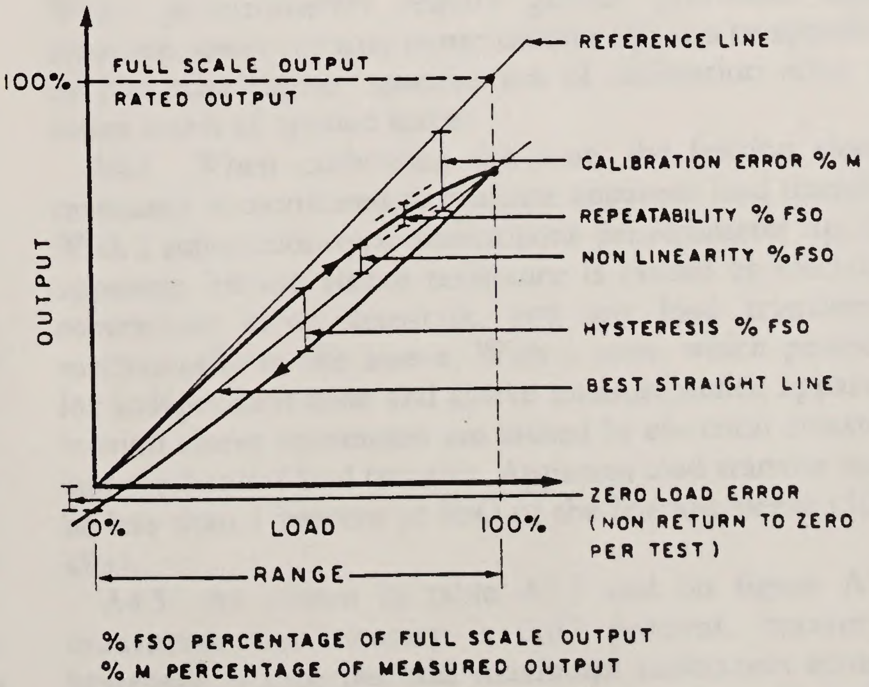


Figure A1.1. – Definition of terms related to calibration (Schaap and Zuidberg, [1] 1982).

temperature-induced apparent load. The variation in zero-load output is affected by temperature fluctuation because temperature compensated strain gauges do not compensate for modulus of elasticity and *K*-factor changes with temperature [1]. Also, penetrometer tips that contain amplifiers can be hindered by temperature shifts if the amplifiers are not temperature compensated [2]. As a result, the zero-load output is to be evaluated at temperatures of 0 and 30 °C for evaluation of thermal stability.

A3.2 Typically, there are two methods to adjust for zero-load variations. With older analog systems, a zero-load output voltage under set amplification and signal conditioning requirements is obtained (method 1). To set this voltage output to zero, simple strip chart adjustments are made to locate the pen at zero load on the chart. The offset of the pen from original zero-load voltage is converted to equivalent drift in terms of cone and friction sleeve resistance by knowing the linear behavior of voltage versus load or by knowing the chart scaling factors. In any case, the drift in zero-load voltage output is converted to changes in apparent cone or friction sleeve resistance.

A3.3 Some newer systems with microprocessors provide "reference baseline" values for cone or friction sleeve resistance which are not equal to zero but are assigned positive or negative values depending on the electronics of the system. The zero-load error is evaluated by taking the difference between new and initial reference baseline values (method 2). For discussions of zero-load error, the term baseline is used for both methods. The term "reference baseline" for older analog systems refer to the "initial voltage at zero load", but zero-load error is expressed as a change in apparent resistance divided by FSO resistance of the cone or friction sleeve.

A3.4 Newly manufactured or repaired penetrometer tips are first cycled to a minimum of 80 percent of FSO — five times at room temperature — to remove any residual nonlinearity. After cycling, an initial reference baseline value is established at room temperature after the cone has been electrically powered for about 30 minutes. To evaluate thermal stability, the penetrometer tip is stabilized at temperatures of 0 and 30 °C and new baseline values are obtained. The change in baseline values must be $\leq$1.0 percent FSO of either cone or friction sleeve resistances.

A4. Load Range Calibration

A4.1 The electric cone penetrometer system is load tested in a universal testing machine or specially designed cone penetrometer calibration device capable of independently loading the cone and friction sleeve. If used, the universal testing machine must be accompanied by a calibration certificate (current within the last year) in accordance with ASTM E 4. If a cone calibration apparatus is used, it should also be accompanied by a calibration document current within the last year. The calibration document shows that applied forces or masses are traceable to standard forces or masses retained by the National Institute of Standards and Technology (National Bureau of Standards). When calibrating subtraction-type penetrometer tips, it is possible to waive the independent sleeve measurement requirement. For requirements on calibrations without independent sleeve loadings, contact the Bureau's Research and Laboratory Services Division, Denver Office, Code D-3760, Denver, Colorado 80225. The universal testing machine or cone calibration devices must be capable of loading the penetrometer tip to 100-percent FSO.

A4.2 Example calibrations of an electric cone penetrometer are shown in tables A1.1 and A1.2 and on figures A1.2 and A1.3. The calibrations were performed on a 10-ton subtraction-type electric cone penetrometer. The measured output was a readout of cone and friction sleeve resistance obtained through a microprocessor based data anyalsis system. An initial baseline was taken and then subtracted to obtain zero resistance at zero load.

A4.3 As shown in table A1.1, the cone is first loaded. This loading is to be performed after the cone is subjected to five cycles of compressive loading and reference baselines, or internal zeroing, have been obtained at room temperature. The cone is loaded in a minimum of seven increments at forces equivalent to 0, 2, 20, 40, 60, 80, and 100 percent FSO for the cone. At each increment of force, both cone and sleeve resistance are recorded. The actual cone resistance is computed by dividing the applied force by the cone base area. The "best straight line" (see fig. A1.1) is determined by drawing a straight line between the origin and the force transducer output of 100-percent rated capacity. The linearity is the difference between measured cone resistance and best-straight line cone resistance divided by the cone FSO. Hysteresis is evaluated by comparing the difference between cone resistance at the same level of applied force in loading and unloading and dividing by cone FSO. Calibration error is calculated by taking the difference between the best-straight line cone resistance and actual cone resistance and dividing by the actual cone resistance. Calibration error becomes larger with smaller measured outputs and; therefore, it is not evaluated at loadings equivalent to less than 20 percent of cone FSO. When penetrometers require greater precision, more sensitive, lower capacity penetrometer tips can be specified by requiring tighter specification of calibration error at lower levels of applied force.

A4.4 When calibrating the cone, the friction sleeve resistance is monitored to evaluate apparent load transfer. With a subtraction-type electric cone penetrometer tip, the apparent friction sleeve resistance is caused by electrical subtraction error, crosstalk, and any load transferred mechanically to the sleeve. With a cone, which provides for independent cone and sleeve measurements, apparent friction sleeve resistances are caused by electrical crosstalk and mechanical load transfer. Apparent load transfer must be less than 1 percent of FSO of the friction sleeve (1000 kPa).

A4.5 As shown in table A1.1 and on figure A1.2, maximum nonlinearity is 0.07 percent, maximum hysteresis is 0.06 percent, maximum calibration error is 0.12 percent, and maximum apparant load transfer is 0.04 percent. For this calibration, the zero load or nonreturn to zero was 0.08 MPa or 0.08-percent FSO.

APPLIED FORCE kN x	MEASURED CONE RESISTANCE qc (MN/m²) y	MEASURED FRICTION SLEEVE RESISTANCE fs (kN/m²)	ACTUAL CONE RESISTANCE (MN/m²) $QA = \frac{x}{10 cm^2}$	BEST STRAIGHT LINE (MN/m²) APPROXIMATION $y' = mx + b$	LINEARITY (%FSO) $\frac{y-y'}{FSO} \cdot 100$ CONE FSO = 100 MPa	HYSTERESIS (%FSO)	CALIBRATION ERROR (% M.O.) $\frac{QA-y'}{QA} \cdot 100$
0	17.51	-130.9	(BASELINE READING)				
0	0	1	0				
2	1.99	4	2.00	2.00	-0.01	0.06	N/A
20	19.99	3	20.00	19.98	0.01	0.06	0.10
40	39.96	0	40.00	39.95	0.01	0.05	0.12
60	59.93	-1	60.00	59.93	0	0.02	0.12
80	79.92	1	80.00	79.90	0.02	0.02	0.12
100	99.88	2	100.00	99.88	0		
80	79.90	1	80.00	79.90	0		
60	59.91	-1	60.00	59.93	-0.02		0.12
40	39.91	0	40.00	39.95	-0.04		0.12
20	19.93	3	20.00	19.98	-0.05		0.10
2	1.93	3	2.00	2.00	-0.07		N/A
0	-0.08	3	0				
0	17.59	-130.7	(BASELINE READING)				

BEST STRAIGHT LINE APPROXIMATION: $y = mx + b$, $m = 99.88/100 = 0.9988$ $b = 0$

ZERO LOAD ERROR: 0.08 MPa ÷ 100 MPa x 100 = 0.08%

MAXIMUM APPARENT LOAD TRANSFER ERROR: 4 kN/m² ÷ 1000 kN/m² x 100 = 0.4 %

M.O. : MEASURED OUTPUT

Table A1.1. – Electric cone penetrometer cone calibration — example.

APPLIED FORCE (kN) x	MEASURED CONE RESISTANCE qc (MN/m²)	MEASURED FRICTION SLEEVE RESISTANCE fs (kN/m²) y	ACTUAL FRICTION SLEEVE RESISTANCE (MN/m²) $FA = \frac{x}{150 cm^2}$	BEST STRAIGHT LINE kN/m² $y' = mx + b$	LINEARITY (% FSO) $\frac{y-y'}{FSO} \times 100$ $FSO = 1000 \frac{kN}{m^2}$	HYSTERESIS (%FSO)	CALIBRATION ERROR (%M.O.) $\frac{FA-y'}{FA} \cdot 100$
0	17.51	-130.9					
0	0	3					
0.3	0	19.79	20.0	19.94	-0.02	0.11	N/A
3.0	0	196.0	200.0	199.4	-0.34	0.20	0.30
6.0	0	396.0	400.0	398.8	-0.28	0.30	0.30
9.0	0	597.0	600.0	598.2	-0.12	0.30	0.30
12.0	0	799.0	800.0	797.6	0.14	0.30	0.30
15.0	0	997.0	1000.0	997.0	0.00		
12.0	0	796.0	800.0	797.6	-0.16		
9.0	0	594.0	600.0	598.2	-0.42		0.30
6.0	0	393.0	400.0	398.8	-0.58		0.30
3.0	0	194.0	200.0	199.4	-0.54		0.30
0.3	0	19.81	20.0	19.94	-0.13		N/A
0	0	-1					
0	17.45	-126.9					

BEST STRAIGHT LINE: $y = mx + b$ $m = 997.0/15.0 = 66.47$ $b = 0.00$

APPARENT LOAD TRANSFER = 0

ZERO LOAD ERROR = 0.1 % FSO

M.O.: MEASURED OUTPUT

Table A1.2. – Electric cone penetrometer sleeve calibration — example.

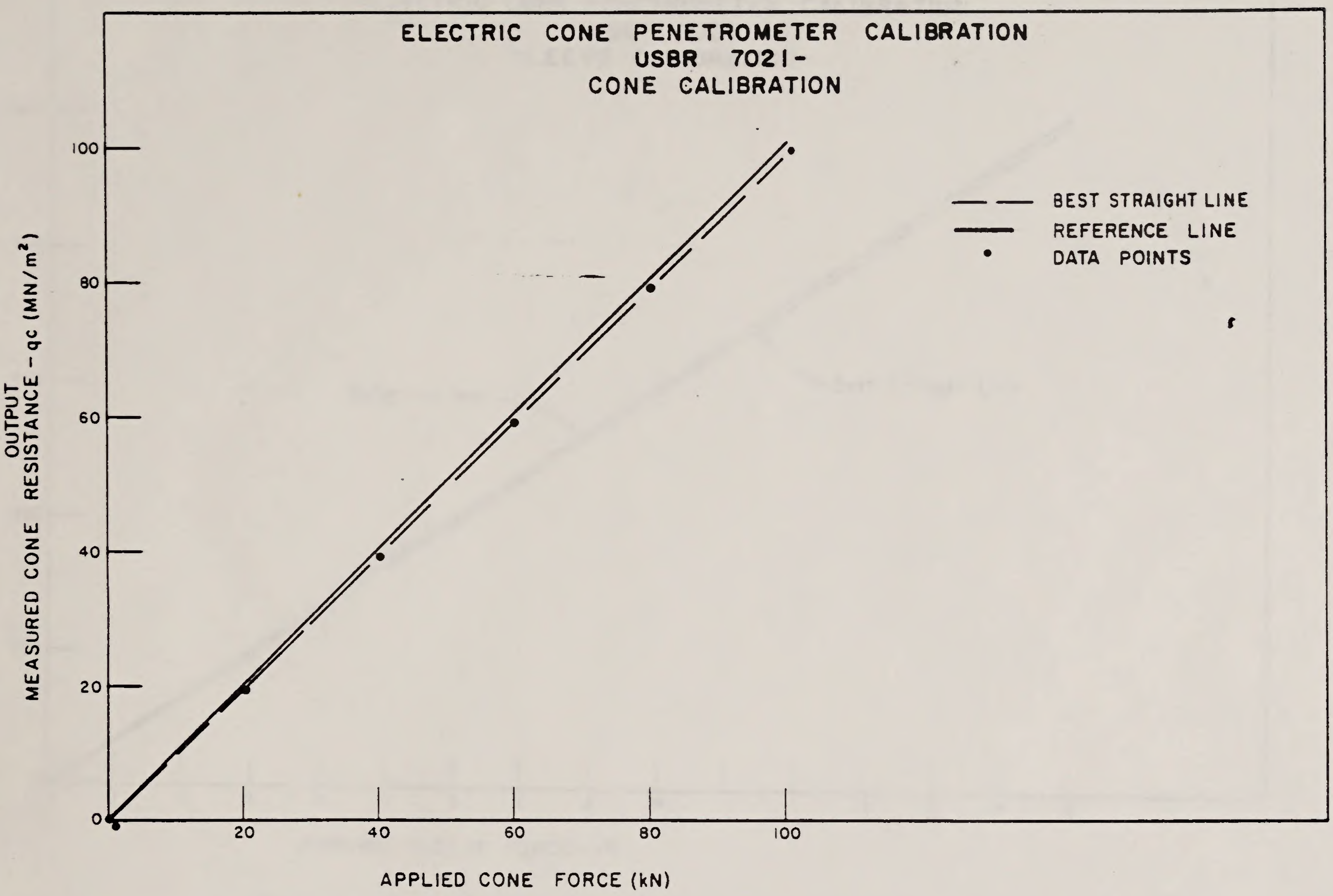


Figure A1.2. - Electric cone penetrometer cone calibration — example plot.

A4.6 Table A1.2 and figure A1.3 show the calibration of the friction sleeve element, independent of cone loading. This is accomplished by removing the cone and loading the bottom edge of the friction sleeve. Again, the forces are applied in seven increments at 0, 2, 20, 40, 60, 80 and 100 percent of FSO, which is approximately 1000 kPa. Nonlinearity, hysteresis, and calibration error are evaluated in the same manner as calibrations for the cone. During friction sleeve calibration, cone resistance is monitored to evaluate apparent load transfer which was not apparent in this calibration. Zero-load error was 0.1 percent FSO on unloading.

A5. Calibration Requirements

A5.1 Calibration requirements developed for electric cone penetrometers are based on past experience with subtraction-type electric cone penetrometers and; as a result of this experience, represent the minimum precision requirement of electric cone penetrometers. In cases where a higher level of precision is required, stricter calibration requirements would be required. Newly manufactured or repaired electric cone penetrometers are required to meet the following requirements:

Calibration parameter	*Element*	*Requirement**
Zero-load error	Cone and sleeve	≤0.5% FSO
Zero-load thermal stability	Cone and sleeve	≤1.0% FSO
Nonlinearity	Cone and sleeve	≤1.0% FSO
Hysteresis	Cone and sleeve	≤1.0% FSO
Calibration error	Cone	≤0.5% MO at ≥20% FSO
	Sleeve	≤1.0% MO at ≥20% FSO
Apparant load transfer	Cone	≤0.5% FSO
	Cone and sleeve	≤0.05% FSO

* Repaired electric cone penetrometers are required to meet these standards in the lower 50 percent of FSO, only.

A6. Documentation of Calibrations

A6.1 Laboratory calibration documents consisting of a short report on the equipment and methods of testing, along with tables and figures similar to those in this annex, are required for the following occurrences:

- When new penetrometer tips are received
- When damaged penetrometer tips are repaired
- In instances when qualifications or proposals are required for contract negotiations

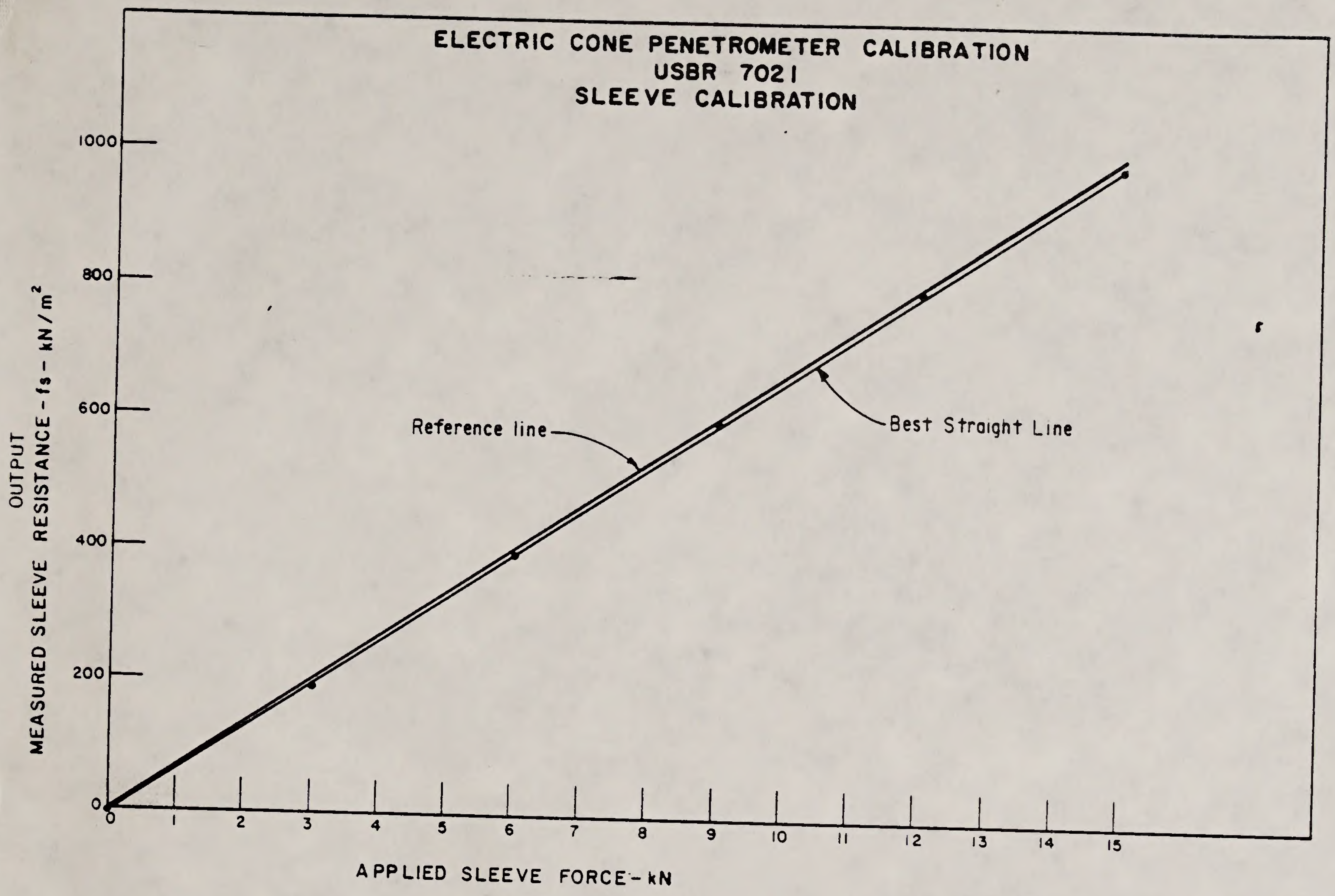


Figure A1.3. - Electric cone penetrometer sleeve calibration — example plot.

A6.2 The report must be certified by a registered professional engineer or other responsible engineer with knowledge and experience in materials testing for quality assurance. Calibration documents are retained on file by the offices responsible for performing soundings and should be updated at required intervals. For contract soundings, calibration documents should be obtained prior to contract acceptance and after testing on unaltered equipment.

A6.3 If the electric cone penetrometer meets the field calibration requirements given in paragraph 11.1.2, it is only necessary to adjust the penetrometer tip to the laboratory requirements on a yearly basis. Electric cone penetrometers should be calibrated using laboratory procedures prior to use on each new project, but they do not need to meet calibration tolerances as required for newly manufactured cones.

A.7 References

[1] Schaap, L.H.J., and H. M. Zuidberg, *Mechanical and Electrical Aspects of the Electric Cone Penetrometer Tip*, Proceedings of the Second European Symposium on Penetration Testing, Amsterdam, May 24-27, 1982.

[2] Robertson, P. K., and R. G. Campanella, *Guidelines for Use and Interpretation of the Electronic Cone Penetration Test*, Soil Mechanics Series No. 69, Department of Civil Engineering, University of British Columbia, Vancouver, Canada, February 1984.

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